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Tech Notes

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Tech Notes

Highlighting Selected U.S. Government Technology & Resources

February 1991

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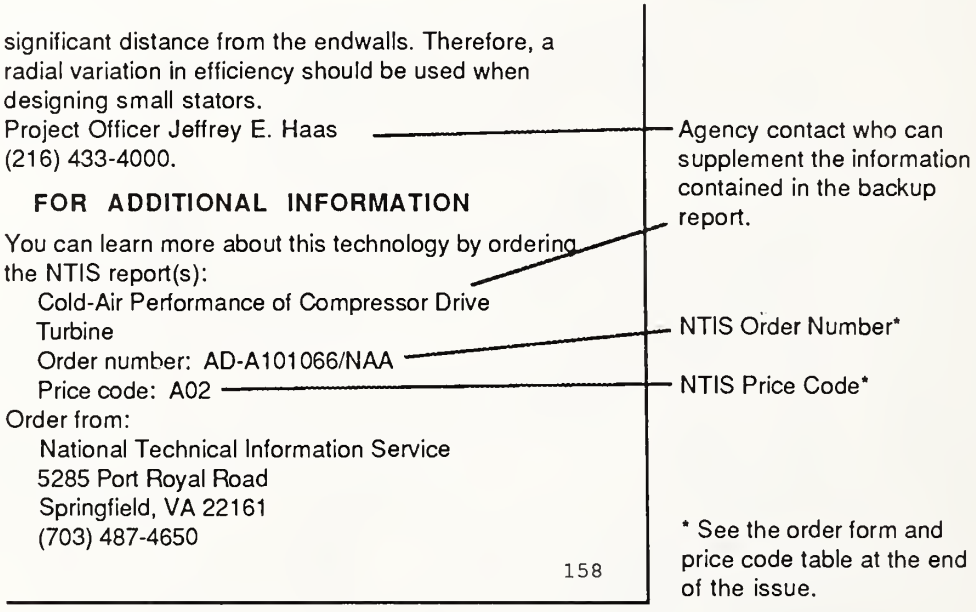
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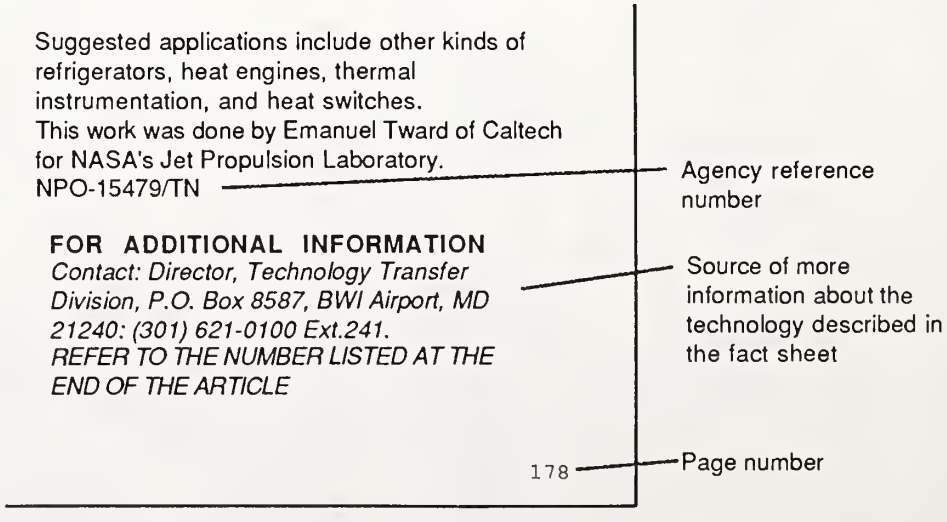
Suggested applications include other kinds of refrigerators, heat engines, thermal instrumentation, and heat switches.
This work was done by Emanuel Tward of Caltech for NASA's Jet Propulsion Laboratory.
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Agriculture & Food

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Research Technology
Agricultural Research Service
U.S. Department of Agriculture

Wilt-Not Maples

Norway maples—graceful, compact trees that thrive in urban areas—are one of the five most popular street and shade trees in the United States. Unfortunately, these trees are often damaged or killed by *Verticillium* wilt.

But Norway maples resistant to *Verticillium* wilt are now a distinct possibility, thanks to the work of ARS scientists Alden M. Townsend and Lawrence R. Schreiber.

Currently, there is no known control or treatment for the disease, which is caused by a microscopic fungus that generally lives in soil.

"All you can do right now is prune out infected parts, water and fertilize the tree, and hope for the best," explains Townsend, a plant geneticist with ARS' National Arboretum in Washington, D.C.

So Townsend and Schreiber started searching among the 13 common varieties of Norway maples for ones with natural resistance to the wilt.

They found two varieties, Jade Green and Parkway, that were not so much resistant as they were tolerant to the fungus.

Technically, being able to withstand the presence of the fungus is considered tolerance, while resistance would be if the organism were not able to infect the tree at all, Townsend explains.

"Jade Green and Parkway Norway maples were able to harbor the same level of infection by the fungus while showing significantly fewer signs of the disease when compared to the most susceptible varieties—Crimson King and Greenlace," Townsend says.

It was the wide variation in response to infection that Townsend found most encouraging.

"The amount of variation means there is definitely potential for improvement by selective breeding—potential to breed a Norway maple not susceptible to *Verticillium* wilt," Townsend says.

Such a breeding program is a possibile future project at the Arboretum, he adds.

One of the findings that surprised Townsend was how long the fungus itself could survive.

"We were able to find the fungus in the trees more than a year after we inoculated them," he says. "We had expected that the fungus would live only a few months at most and certainly not after a winter."

The ability of the fungus to survive so long suggests breeding a nonsusceptible Norway maple is as important as finding a treatment.

Alden M. Townsend and Lawrence R. Schreiber are with the U.S. National Arboretum, 24th and R Streets, N.E., Washington, DC (202) 475-4824. ◆

Research Technology
Agricultural Research Service
U.S. Department of Agriculture

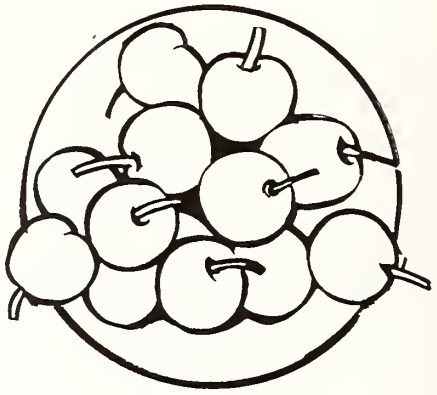
Estimating Fumigant Residues

A new method to gauge fumigant residues in fruits and other agricultural products could lead to improved safety for handlers, shippers, and consumers.

ARS chemist Charles R. Sell devised a computer-based, mathematical model to estimate how much methyl bromide, a widely used fumigant, remains in produce after fumigation. Residues of this highly penetrating toxic gas may seep from commodities during storage or transport, so it's important to make sure the produce is safe to handle and consume after fumigation.

Currently, fruit or other produce is tested directly—by crushing and blending it and measuring the methyl bromide present with a gas chromatograph. In contrast, the new model measures residues indirectly. An instrument determines the amount of methyl bromide in the exhaust air blown from the fumigation chambers and then transmits that number to a computer. The model computes the amount of methyl bromide remaining in the commodity, taking into account a host of variables, such as type and amount of fruit, temperature, and other conditions.

Sell and co-inventor Mark A. Weiss verified the model's accuracy by comparing estimated values with actual measurements. Both researchers are with the Fruit and Vegetable Insect Research unit in Yakima, Washington.



Codling moth larvae and eggs may lurk in cherries and apples after harvesting, and foreign consumers, notably the Japanese, don't want the pest introduced to their country. Methyl bromide provides an effective and accepted treatment for eliminating the hidden pests. But Japan requires that residues of methyl bromide in fumigated commodities not exceed 10 parts per billion.

This innovation will improve current fumigation practices by speeding up residue measurements, Sell says. He's applied for a patent on the new model, which can be scaled up for commercial operations.

Charles R. Sell and Mark A. Weiss are with the USDA-ARS Fruit and Vegetable Insect Research Unit, 3706 W. Nob Hill Blvd., Yakima, WA 98902 (509) 575-5967. ◆

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Sandia National Laboratory

Neural Network Detects Targets Regardless of Perspective

Advances in computer software and hardware have produced a neural network that for the first time can process a video camera image within seconds and detect targets placed at different angles and positions among other objects.

Until now, neural networks have been unable to process a raw video image, relying instead on the ability to analyze and identify features of a target, such as lines or boxes.

The improved network, developed by scientists at Sandia National Laboratories, is also able to recognize targets in new and different perspectives after being trained with visual information from targets in similar orientations. The capability, called generalization, has previously been possible only for rotations in two dimensions.

Neural networks are data processing systems modeled loosely after the networks of nerve cells in the brain and nervous system. Unlike conventional computers, neural networks can "learn" to do various tasks by trial and error without special programming, giving them significant advantages for use in interpreting speech, images, and other data involving complex pattern-recognition problems.

The new software algorithm and hardware developed at Sandia enable a neural network to recognize a target both when pivoted on an axis and when moved to different locations on a "terrain board," a miniature landscape similar to those used for model trains. Previous algorithms gave neural networks the power to recognize a target when pivoted "in-plane" on a stationary axis, a capability called "rotation invariance." The new system has the added capability of being both "shift" and "perspective invariant," meaning it is capable of identifying targets that have been moved to change both their position and perspective from the camera's point of view.

Recognizes image in 4 seconds

"Shift invariance is also important because you need to be able to recognize the target no matter where it is in addition to its being rotated," says Joe Fogler, who designed the system's hardware.

Sandia's research on neural networks is primarily directed toward military applications, such as developing a system that is able to distinguish a tank from other vehicles and objects.

The system developed by Fogler, Mary Moya, and Larry Hostetler of Sandia's Exploratory Systems Development Division consists of a video camera, an image digitizer, the processing hardware, and video screen displays. When the camera is focused on the terrain board, the system is able to distinguish miniature tanks from other objects such as model-size house, trees, or automobiles 91 percent of the time.

The image recognition process takes about four seconds on the enhanced software compared with about four hours on a standard scientific workstation such as a Sun 3. The hardware was built by arranging commercially available image processing modules in new configurations, giving the system a performance speed of 2.5 billion connections per second. Sandia is now looking at a next-generation design that for the first time would push performance speed beyond a trillion connections per second.

The system's speed comes from a combination of the enhanced hardware and the neural network's unique way of processing image information.

Like the brain, neural networks receive stimuli and generate responses. The brain's response is generated through learning, which scientists believe may involve a strengthening of connections between nerve cells.

Learns correct responses

Emulating biological neurons, artificial neural networks consist of a collection of processing elements or nodes. The outputs of the nodes in each layer become the input for the next layer of processing elements. The third layer of the network generates the system's response to the initial stimuli.

Learning is accomplished as a network is fed correct responses and adjusts the strength of its signals in favor of the correct response. Eventually, the neural net learns to weight each signal appropriately.

Other algorithms typically make sequential calculations from start to finish along each node of the network. The Sandia system gains its speed by calculating all nodes in a layer of the network simultaneously.

Moya says that the Sandia system also differs from other systems in that it is able to analyze raw pixel (short for picture element) data. Other researchers have tackled the problem by extracting features, such as lines and

boxes, from the image data and training the network to recognize such features. In the Sandia system, the camera's image is digitized, and each pixel is assigned a number depending on its brightness or darkness.

The system is trained by feeding it "training sets," numerical data representing images of miniature tanks and non-tanks from different perspectives. Instead of training the computer once, Moya uses multiple training sets. The initial training set consists of examples of tanks and other objects. The computer is then tested on its ability to recognize miniature tanks.

When it gives the wrong answer—which would consist of a negative number for a non-tank—Moya supplies it with the correct information. By comparing right and wrong answers in a process called back propagation, the network adjusts itself in favor of the correct answer.

Subsequent training sets are derived from the network's past mistakes. The more the process is repeated, the more accurate the network becomes. Called interactive training, the technique allows researchers to improve the computer's accuracy.

"It forces a network to learn very specifically what is and is not a tank," Moya says. "It's not perfect, but it's a lot better than if you just trained it one time."

Another significant improvement found in Sandia's system is that it is capable of three-dimensional generalization. Generalization in target-recognition neural networks is the ability to interpolate that an object is a target based on information stored on targets in similar orientations. For example, a network capable of generalization could be supplied information on a tank viewed from two different angles and could identify a tank placed at an intermediate angle. Other systems have demonstrated two-dimensional generalization. □

FOR ADDITIONAL INFORMATION

Public Information Division,
Code 3161,
Department of Energy,
Sandia National Laboratories,
Albuquerque, NM 87185-5800
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Refer to announcement 25 No. 9

10-Layer Electronics Board Simplifies Data Processing

Ames Laboratory physicists and engineers have designed a multilayer printed circuit board that converts huge amounts of analog information to digital signals, thus simplifying data processing and storage.

The board was designed for use in a high energy physics experiment at CERN, the European international center for particle physics. It is also well-suited for applications in nuclear medical imaging, astronomy, and other areas of science where "blanket" sampling results in the collection of vast amounts of data.

A common problem in taking blanket samples is that a large amount of unnecessary information, essentially noise, is also collected. For example, in the DELPHI (Detector for Electron Lepton Photon Hadron Identification) experiment, which required 600 of these boards, 4 1/2 million regions of space inside an electromagnetic calorimeter are scanned. However, after the data are collected, useful information is found in only 30,000 to 40,000 of these regions.

To eliminate the unnecessary background, or "noise", and achieve what is called zero-supression, Ames Lab's scientists and engineers designed the board's circuitry in such a way that data is not counted as "valid" unless it generates a signal level above that of the ambient backgrounds and unless a minimum number of contiguous signals pass this criteria.

The board itself is comprised of 10 circuit layers and houses 32 FLASH ADCs (Analog to Digital Converters). These ADCs are able to sample information at the rate of 15 million times per second, and convert each sample to eight bits of digital information. Using a bilinear conversion scale, a dynamic range of 800 to 1 is achieved.

A unique feature of the design is the extensive use of programmable logic components, especially to control the zero suppression. Another novel aspect is the extensive distributed processing capability. Each board contains a microprocessor that allows digitized data to be reformatted and allows calibration tasks to be performed efficiently.

The board, which measures 14.4 by 15.8 inches, conforms to IEEE standard (IEEE 960-1986) FASTBUS, making it compatible with the data acquisition and control systems used in most experimental and educational laboratories.

Literature: H. B. Crawley, M. S. Gorbics, G. E. Holland, J. F. Homer, Jr., R. McKay, W. T. Meyer, E. I. Rosenberg, and W. D. Thomas, "The DELPHI Barrel Electromagnetic Calorimeter Flash ADC Based Digitizer," *IEEE Trans. Nucl. Sci.*, NS-34, p. 261, 1987.

Patent/License Status: U.S. Patent application filed.

Potential Applications/Spinoffs: Nuclear medical imaging, astronomy.

FOR ADDITIONAL INFORMATION: Contact Daniel E. Williams, Office of Research and Technology Application, Ames Laboratory, 119 Office and Laboratory, Iowa State University, Ames, IA 50011 (515)294-2635.

U.S. Navy Fact Sheet

Naval Surface Warfare Center

Crosstie Random Access Memory

The Crosstie Random Access Memory (CRAM) is a nonvolatile computer memory which can be made very resistant to radiation effects if hardened circuitry is used.

It has the potential to replace core memories with the added feature of nondestructive readout. It will cost less, have much less weight, and need less volume. If we consider a 4K(64 x 64) array, we can have a 50 nsec write time, and about a 200-500 nsec read time. Decoders and drivers must be on the same chip. Since only one lead is required for the amplifier, it does not have to be on the chip. Larger arrays are possible with increased access time. An access time of less than 200 nsec can be obtained if the parasitic capacity is balanced out.

The above access times were estimated at room temperature and they will become longer at higher temperatures.

The CRAM could be written with coincident current pulses as short as 20 nsec. Nondestructive reading was accomplished in 800 nsec and this can be improved considerably with better design.

There are several versions of the CRAM. In one version permalloy film is etched into proper shapes so a crosstie-Block-line pair is used to store a "one", the absence of the crosstie-Block-line pair signifies a "zero." The resistance of the memory element differs depending on whether a crosstie- Block-line pair is present or not. This difference in resistance is used to read out the memory. Another version moves a Block line between two stable positions.

Descriptive Literature: IEEE Transactions on Magnetics, Vol. MAG-18, No. 6, November 1982, pages 1776-1778.

Literature Available From: Mr. Leonard J. Schwee, NSWC/WO, Code R41, (301-394-2690), Naval Surface Warfare Center, Silver Spring, MD 20903-5000.

FOR ADDITIONAL INFORMATION: For information on licensing of this technology disclosure, contact the Naval Surface Warfare Center, Mr. Ramsey D. Johnson, Code D4, or by telephone at 301-394-1505.

U.S. Navy Fact Sheet

Naval Surface Warfare Center

Data Acquisition and Reduction Processor (DARP) for AN/UYK-43(V) Performance Monitor Interface (PMI)

The Data Acquisition and Reduction Processor (DARP) is a system of hardware components controlled by custom software and hardware resident in the DARP Control Computer (DCC). The DARP attaches to and captures data presented on the Performance Monitor Interface (PMI) of the AN/UYK-43 large scale militarized computer that replaces the AN/UYK-7 large scale militarized computer.

The requirement for an optional PMI on each Central Processor Unit (CPU) and each Input/Output Controller (IOC) was included in the original procurement requirements for the AN/UYK-43. The PMI provides passive access to numerous types of data that reflect the operation of the CPU and IOC. Special performance monitoring instructions are included in the Instruction Set Architecture (ISA) of the AN/UYK-43 to allow programs to pass specific data to the PMI.

The DARP provides the capability to capture AN/UYK-43 PMI presented data at the presentation speed of the AN/UYK-43. A time-tag is associated with each captured data word to allow correlation of data captured on multiple PMI data busses or to measure the time between the capture of multiple data items or events. Captured data are stored in the resident DARP memory for later retrieval and into first-in-first-out (FIFO) buffers for immediate retrieval and processing.

The AN/UYK-43 PMI and the DARP combine to open enormous possibilities for the evaluation of AN/UYK-43 hardware performance, overall system performance, and the support of software debug and analysis for AN/UYK-43 hosted combat system elements. Some general functions include (1) passive program trace, (2) monitoring of the active status register, (3) capture of program generated data by using the performance monitor instructions, and (4) evaluation of CPU and IOC loading in a particular system configuration. Although the PMI can operate with no AN/UYK-43 resident program support, detailed evaluations will be greatly enhanced by using carefully selected support mechanisms.

Methods utilized to evaluate system timing and performance in previous systems included (1) performing an input/output (I/O) process under system software control on an unused I/O channel and performing timing measurements with an oscilloscope; or (2) accessing a 1-μs accurate external clock through an I/O channel and extracting the timing information through another I/O channel to magnetic media for later analysis. The first method required little processing support from the system under test but, because of varying frequencies, large sample periods, and oscilloscope operator interaction, yielded fairly gross timing results. The second method yielded accurate results but placed a processing burden on the system under test, which could adversely impact the system as well as the timing results. Application of the DARP on an AN/UYK-43 should provide accurate timing data.

Although the DARP was designed for the AN/UYK-43 PMI, the DARP can be adapted to any interface that provides a signal to define that data are valid for sampling at a frequency not to exceed 6.67 MHz. DARP systems are currently in use with AN/UYK-44s and ROLM 1666Bs as well as AN/UYK-43s.

FOR ADDITIONAL INFORMATION: Ramsey D. Johnson (Code D4), Naval Surface Warfare Center, 10901 New Hampshire Avenue, Silver Spring, MD 20903-5000; (301)394-1505.

NASA Tech Brief
National Aeronautics and Space Administration

NASA's Jet Propulsion Laboratory, Pasadena, California

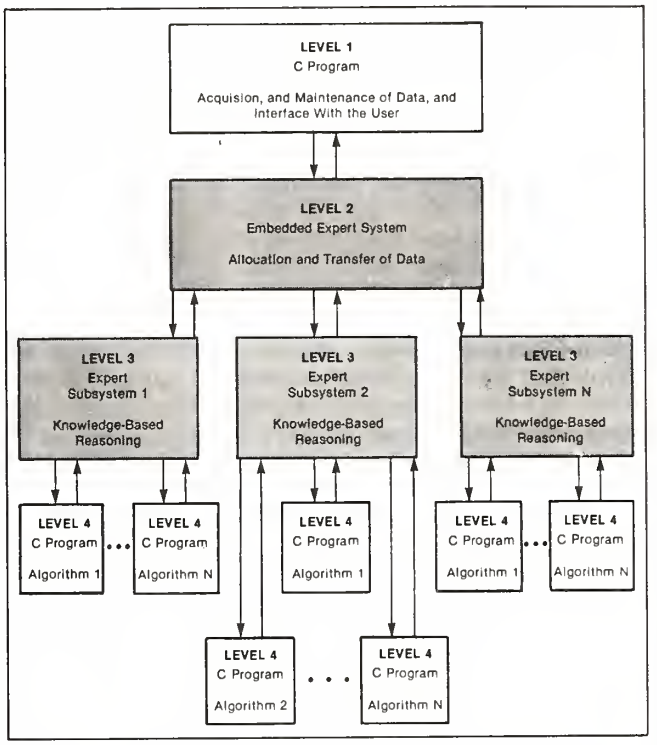
Cooperating Expert Systems for Automated Monitoring and Diagnostics

Human operators will be freer to perform nonrepetitive tasks.

An expert software system for monitoring multiple streams of sensory data from interacting equipment subsystems is undergoing development. The original version of this software is intended to assist human analysts in the interpretation of telemetry data that indicate the operating statuses of the subsystems of a spacecraft, enable the analysts to maintain the desired mode(s) of operation, and help the analysts to correct anomalies in the subsystems or in the overall spacecraft system. Other versions could be devised for industrial monitoring and analysis tasks that are similarly complicated.

Computer automation of the monitoring task offers several advantages. First, it relieves the human operators of the repetitive and boring task of routine monitoring, waiting for malfunctions that occur infrequently and unpredictably. By so doing, it frees the analysts for more challenging, nonroutine tasks. Another advantage is the preservation of routine and reportable components of expertise in the face of changes in personnel. Yet another advantage is provision for the integrated analysis of data from multiple spacecraft (or equipment) subsystems in cases in which a malfunction in one equipment subsystem can manifest itself in changes in the sensory data from other equipment subsystems.

The expert software system is organized hierarchically to monitor multiple spacecraft (or equipment) subsystems (see figure). In this software hierarchy, each software module has its own separate knowledge base, each with its own inferencing process. All the knowledge bases are incorporated into the same software hierarchy. A top-level (level-1) program performs functions relevant to access to data, maintenance of data, and interface with the user(s). This level also passes data to the level-2 expert system, which allocates the incoming data to the appropriate third-level expert system for analysis. Each third-level expert system contains production rules for a single (spacecraft or equipment) subsystem. These perform analyses to identify anomalous situations and provide recommendations for corrective action. They also report their findings upward to the second-level expert system, which may pass the findings downward to another third-level expert subsystem for appropriate action, depending upon relevance. At the fourth and lowest level of the hierarchy are small programs that perform algorithmic analyses as requested by the expert subsystems.



The **Expert Software System** is organized hierarchically to monitor multiple equipment subsystems simultaneously. Each expert software subsystem is responsible for one of the equipment subsystems.

For maximum speed and portability, the top- and bottom-level programs are written in C. The expert system and subsystems located in the second and third levels, respectively, are programmed in an expert-system software shell that makes it possible to embed the expert system into higher-level C code and enables the expert subsystems to call lower-level external functions.

A prototype expert software system for monitoring three spacecraft subsystems has been tested successfully on the Sun 4 workstation. However, to add the second expert system for coordinating the analysis of multiple spacecraft subsystems in nearly real time, it may be necessary to transfer the software to other computing equipment that supports higher speed and multiprocessing.

This work was done by Ursula M. Schwuttke and John R. Veregge of Caltech for **NASA's Jet Propulsion Laboratory**. *NPO-17804/TN*

FOR ADDITIONAL INFORMATION: *Contact: Director, Technology Transfer Division, P.O. Box 8757, BWI Airport, MD 21240; (301) 621-0100 Ext. 241*
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NASA Tech Brief
National Aeronautics and Space Administration
Lyndon B. Johnson Space Center, Houston, Texas

Data-Acquisition Board for IBM PS/2 Computer

A plug-in unit reads in as many as 48 signals.

A circuit board containing microprocessors is designed to control the acquisition of data by an IBM PS/2 computer. The board is to be plugged into one of the 16-bit slots on the mother board of the computer. Its purpose is to read in a number (up to 48) of discrete signals and transfer them to the Micro Channel interface of the computer to be processed. Data can be read in through one, any combination of two, or three 16-bit channels at a rate of ~1 MHz overall or ~0.33 MHz per channel. With later expansion of software, the board will also be able to recognize and filter specified kinds of signal patterns, possibly to detect errors.

An 80186 microprocessor is used to take in 48 discrete samples via a switching process (see figure). This microprocessor stores the data in a set of first-in/first-out buffers (FIFO's) at a rate as close as possible to 10^5 bytes/second. As new data are written into the FIFO buffer, older data are withdrawn from the FIFO according to the first-in/first-out sequence. Essentially, each "half-full" flag calls for a block direct-memory-access (DMA) transfer of 256 words of data to the PS/2, in burst mode, or for the beginning of a sequence of single transfers. In the latter case, a DMA request is initiated at the beginning of each bus cycle.

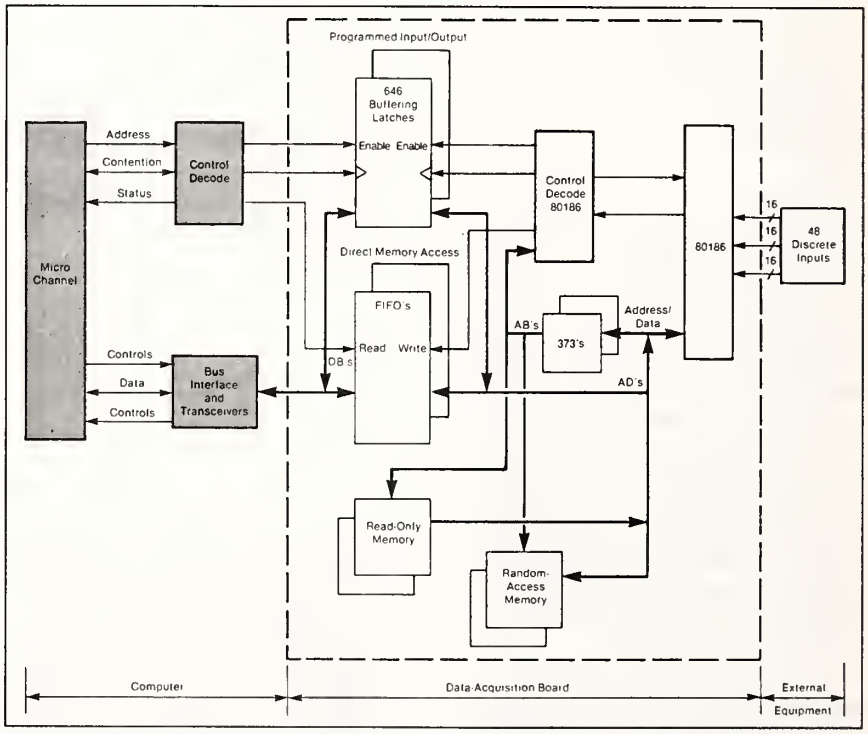
After the FIFO's are half full, a sequence of DREQ's (DMA requests) takes place within the board logic, and thus within the interface logic, at the beginning of each bus cycle. This is called the single-transfer DMA Mode. As soon as the DREQ input to the Micro Channel bus interface 82C612 is asserted, the local arbiter of the interface logic places its priority assignment on the arbitration bus. If it has the highest priority among all contestants or if it is the only contestant, it has control of the bus. However, for each transfer, it has to repeat the same routine to compete for the system bus. In case it loses its turn, it has to keep the DREQ line active and thus preempts for another arbitrating cycle, attempting to gain control of the bus.

Once the FIFO's are half full, the "half-full" flag clocks a DMA request for a block of 256 words of data to be read to the Micro Channel DMA controller. Then, the "terminal count" signal from the Micro Channel bus clears this request.

In addition to the DMA data-transfer scheme, the board also supports a program-control implementation of input and output transfers (PI/O) between the 80186 microprocessor and the Micro Channel. For this purpose, there are two control registers, designated "BASE + 00h" and "BASE + 01h." In addition, there are six 646 buffering latches (designated "BASE + 02h" through "BASE + 07h") designed to communicate between the Micro Channel and 80186 data buses. To gain access to the PI/O mode, one simply sets the PIO/DMA bit (bit 1) of control register BASE + 00h to 1.

There are two types of PI/O transfer. In the first type, known as word transfer, each WRITE to input/output registers BASE + 02h (low byte) and BASE + 03h (high byte) from the PS/2 latches the designated data onto the buffer. Through interrupt handshaking (80186 INT0 or INT1), the 80186 reads data from the buffer and processes them (if suitable firmware is implemented). PI/O WRITE from the 80186 also causes the PS/2 to read from the registers BASE + 04h (low byte) and BASE + 05h (high byte) through Micro Channel interrupt requests, which are to be selected within the programmable-option-select registers.

The second type of PI/O transfer is known as byte transfer and is similar to word transfer. However, only the low byte latch is used. Data written to the high byte should all be zeros.



The **Data-Acquisition Board** controls the transfer of data from as many as 48 discrete channels to the Micro Channel interface.

This work was done by Phuong-Dung T. "June" Hoang of **Johnson Space Center.** *MSC-21590/TN*

NASA Tech Brief
National Aeronautics and Space Administration
Lyndon B. Johnson Space Center, Houston, Texas

Master/Programmable-Slave Computer

Features include versatility, low power, and large memory.

A unique modular computer features compactness, low power, mass storage of data, multiprocessing, and the choice of various input/output modes. Although the computer is designed for use in the control of a complicated bioreactor and associated experiments, its modular, versatile nature makes the general design concept adaptable to industrial process control with selectable degrees of automatic control, automatic and/or manual monitoring, and manual intervention.

The computer includes a master processor and 24 slave processors. Each processor is mounted on a circuit card in a 25-slot card cage (see Figure 1). The primary functions of the master processor are to program the slave processors for operations based on random-access memory, to regulate and provide communications between slave processors, to transfer data to and from a mass storage device, and to act, when so required, as an interface between the computer and a human operator. The master processor monitors the slave processors for proper operation and is equipped to reset a slave processor that is not functioning properly. In addition, the master can reset or reprogram any slave at will. When power is first turned on or when the master commands a reset, all the slaves wait for permission from the master to run their application programs.

The slave cards do not perform any managerial functions and are dedicated to process-control functions. Each slave card — a computer in itself — is equipped with a number of different input/output capabilities so that it can communicate with the process or equipment that it controls, with the master processor, and with the other slave processors (see Figure 2). A slave processor sends information to another slave processor by "flagging down" the master processor and sending the information to the master processor along with instructions as to where the information is to go. Each slave card can, when necessary, operate independently of the master and the other slaves, processing input/output data by use of its own control program. Each slave card is specialized for its assigned process or external equipment by the inclusion of such input/output devices as analog-to-digital converters, memories, and driving amplifiers for dc motors, stepping motors, and relays.

This work was done by David Smaistrla and William A. Hall of KRUG International for **Johnson Space Center.**
MSC-21550/TN

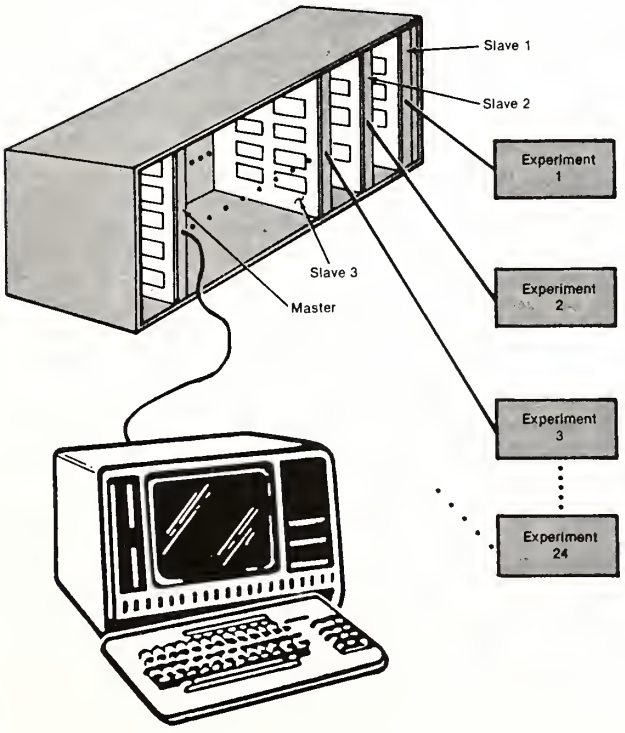


Figure 1. The **Master Processor Communicates With the User** via the usual keyboard and video display terminal. The master processor coordinates the operations of as many as 24 slave processors, each dedicated to a different experiment.

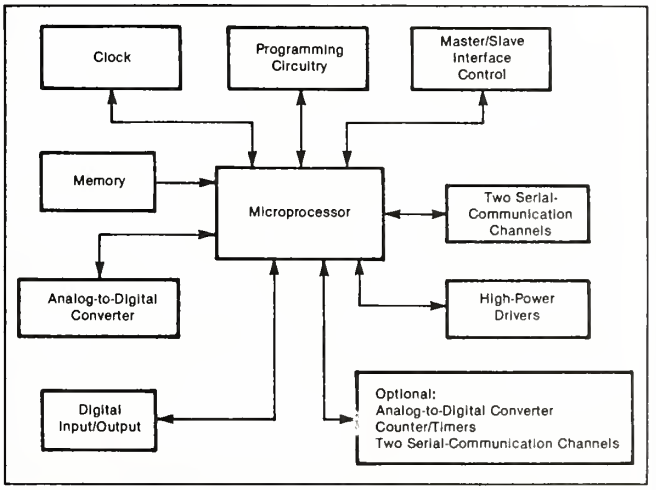


Figure 2. Each **Slave Circuit Card** includes the slave microprocessor and an assortment of input/output circuits for communication with external equipment, with the master processor, and with other slave processors.

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NASA Tech Brief
National Aeronautics and Space Administration
NASA's Jet Propulsion Laboratory, Pasadena, California

Forward Stochastic Nonlinear Adaptive Control Method

The main advantage is simplicity of programming and reduced complexity with clear performance/computation trade-offs.

A promising new method of computation for optimal stochastic nonlinear and adaptive control is undergoing development. Essentially, the new approach is to solve systematically the stochastic dynamic programming equations forward in time, using a nested-stochastic-approximation technique.

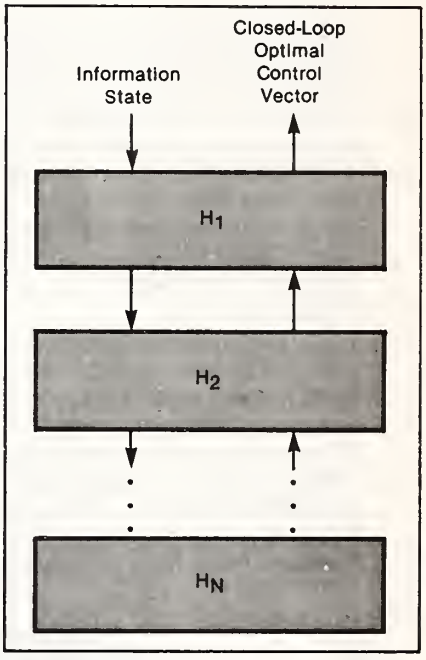
The system in question is represented by discrete-time nonlinear state and measurement equations. The system state, which is assumed to be only partially observed, is specified by a probability density at the initial time. The process and measurement equations include noise, the discrete-time components of which are represented by sequences of zero-mean white-noise vectors that have mutually independent components. These noise vectors are statistically independent of the random initial state, and have process statistics specified by known probability densities.

The optimal-control problem is to minimize a specified cost function over the class of admissible control policies. An admissible control policy is defined by a sequence of control vectors, each of which maps the information state (the measurement information causally available at a given instant) into the input vector at that instant.

Using a forward method, the optimal control vectors are computed along a specific realization of the optimal trajectory through state space. At each instant, only those future optimal trajectories causally related to the present information state are considered. The computational architecture for this approach involves a cascade of "H blocks" (see figure). At the top of each H block, the information state is read in, and the corresponding closed-loop optimal control vector is read out. At the bottom of each H block, the future information states that correspond to the simulated trajectories are read out, and the corresponding closed-loop optimal control vectors are read in. This forward approach is quite different from the classical approach, in which the stochastic dynamic programming equations are solved backwards in time — a procedure that embeds the problem into a larger one and requires computation of the optimal solution over the entire state space.

Although this approach involves much computation, it is simple to program on a computer, and it provides a straighforward numerical solution for problems of this kind. Furthermore, it provides an alternative to the usual "curse of dimensionality" associated with solving the dynamic programming equations backward in time; the "curse" takes a new form in which the amount of computation depends on the amount of uncertainty in the problem and the length of the horizon. As a matter of significant practical interest, it is shown that the cost of computation decreases monotonically as the complexity of the algorithm is reduced. This feature provides a strategy for suboptimal control with clear tradeoffs between performance and the amount of computation.

This work was done by David S. Bayard of Caltech for **NASA's Jet Propulsion Laboratory**. *NPO-17861/TN*



The **Computational Architecture** for the new method involves a sequence of subalgorithms called "H blocks," which can be cascaded.

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NASA Tech Brief
National Aeronautics and Space Administration
NASA's Jet Propulsion Laboratory, Pasadena, California

Licensing Opportunity

Neural-Network Processor Would Allocate Resources

Global optimization problems could be solved quickly.

A proposed artificial neural network would perform a globally optimal allocation of *M* resources among *N* expenditures according to a prescribed set of rules. The concept of the network has evolved during the continuing effort to understand biological neural networks and to develop electronic networks that imitate some of their functions. Potential applications of the proposed resource-allocating processor include the assignment of jobs, scheduling, dispatching, and planning of military maneuvers.

The processor would include a matrix of $M \times N$ cells, each of which would represent the pairing of one of the resources with one of the expenditures (see Figure 1). The cost of the pairing would be stored in analog form in each cell. For each row and each column, a constraint superneuron would ensure that the number of active neurons within the row or column falls within a desired range.

Each constraint superneuron would be programmed with the minimum and maximum number of neurons allowed to be active in its row or column. If the actual number of active neurons were outside this range, the superneuron would generate an inhibitory or excitatory signal that would be presented in parallel to the neurons of that row or column. A global constraint superneuron could also be used to constrain the total number of active neurons to a desired range.

The structure of a neuron cell is shown in Figure 2. An adder circuit would sum the inputs on the row, column, and global-excitation and inhibition lines; the cost of pairing in this cell; and a simulated-annealing term for avoiding local minimum solutions.

The output of the adder would be routed through a circuit that would execute a sigmoidal thresholding function to control the gain and dynamics of the system; the resulting value would be added to the row and column summation lines. A global summation line could be derived by adding across all row or column summation lines. Simulated annealing would be performed with the help of an analog noise generator scaled by a multiplier or, alternatively, by varying the slope of the threshold function. The system would settle into a stable state consistent with the given set of constraints with a convergence time dictated by the

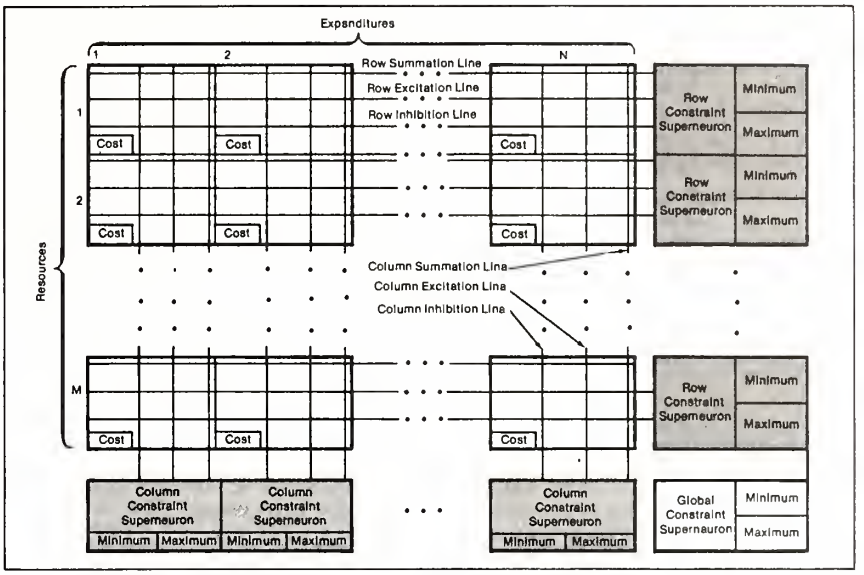

Figure 1. **The Neural-Network Processor** would optimize the allocation of M resources among N expenditures according to the cost of pairing each resource with each expenditure and subject to a limit on the number of resources that can feed into each expenditure and/or a limit on the number of expenditures to which each resource can be allocated.

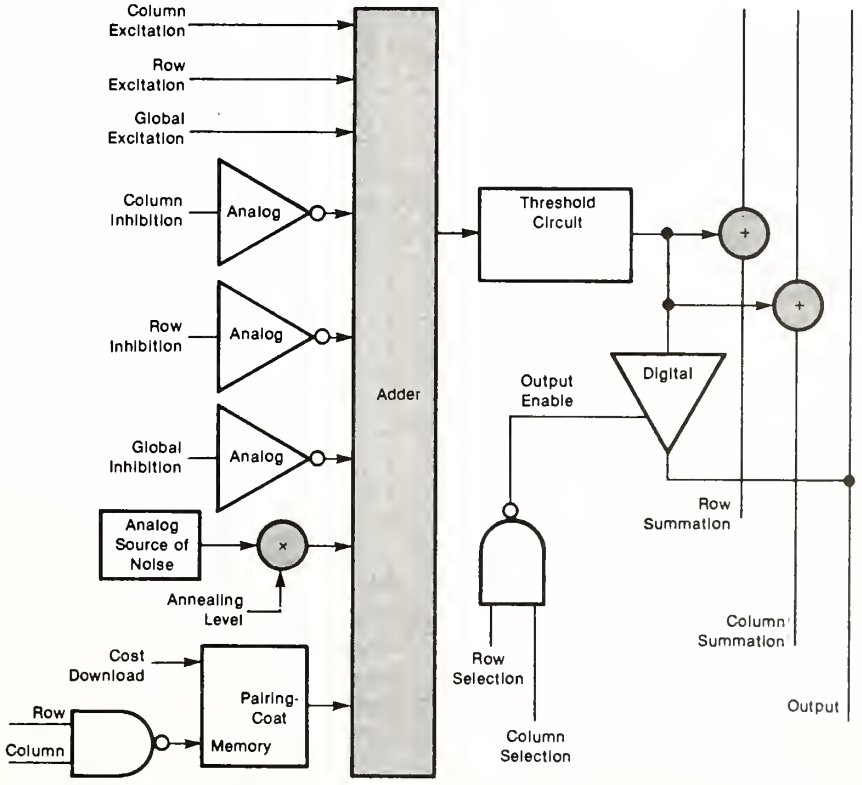

Figure 2. **One Cell** of the neural-network processor would perform several analog and digital functions.

neuron response time and the annealing state. The state of each neuron could be read by using a multiplexer to poll each cell or each row.

This work was done by Silvio P. Eberhardt and Alexander W. Moopenn of Caltech for **NASA's Jet Propulsion Laboratory.**

Inquiries concerning rights for the commercial use of this invention should be addressed to the Patent Counsel, NASA Resident Office-JPL. Refer to NPO-17781/TN.

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NASA Tech Brief
National Aeronautics and
Space Administration

Using Expert Systems for Computational Tasks

A transformation technique may enable inefficient expert systems to run in real time.

A paper suggests the use of a knowledge compiler to transform the knowledge base and inference mechanism of an expert-system computer program into a conventional computer program. The main benefit would be faster execution and, therefore, reduced processing demands. In avionic systems, for example, the transformation would reduce the need for special-purpose computers.

The paper presents an overview of expert systems and a brief comparison of expert-system programs with conventional programs. It discusses applications of expert systems to avionics and explains the concept of the knowledge compiler by using examples of forward- and backward-chaining systems.

Expert systems offer an aircraft pilot both knowledge and assistance. They help the pilot cope with the complexities of, and interactions among, subsystems in new aircraft. Indeed, expert systems may provide the only way of dealing with some advanced aircraft. However, expert systems impose a heavy computational burden — a burden that must be executed in real time in an aircraft. Expert systems operate by iterative processes that are necessarily inefficient, and the inefficiency increases with the size of the knowledge base.

The transformation of the rules of an expert system into conventional computer code yields a logically equivalent representation of the knowledge base and inference mechanism. Of course, the flexibility of the expert system has been changed into the rigidity of a conventional code — but if the transformation is done automatically, nothing is lost. Furthermore, the program thus generated can be executed much faster and by any number of processors.

The transformation would be done by a knowledge compiler in a process reminiscent of that of a standard compiler. When the knowledge base in the expert system is modified, the compiler would generate a new conventional source code; the old code would be discarded.

The transformation concept is not limited to applications in avionics. In research and development laboratories, for instance, symbolic processors offer many benefits but tend to be costly single-user, special-purpose systems. The transformation technique would convert such expert systems from symbolic processors to numeric processors that can be used on widely available general-purpose computers.

This work was done by Eugene L. Duke, Victoria A. Regenie, and Marylouise Brazee of **Ames Research Center** *and Randal W. Brumbaugh of PRC Kentron. Further information may be found in NASA TM-88263 [N86-24687], Price Code: A02 "An Engineering Approach to the Use of Expert Systems Technology in Avionics Applications."*

Copies may be purchased from the National Technical Information Service, Springfield, Virginia 22161, Telephone No. (703) 487-4650. Rush orders may be placed for an extra fee by calling (800) 336-4700. *ARC-12137/TN*

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NASA Tech Brief
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Schedule-Report-Generator Computer Program

Engineering managers can monitor scheduled tasks assigned to staff members.

The Schedule Organizer (SO) (COSMIC Program MSC-21525), Schedule Tracker (ST) (COSMIC program MSC-21526), and Schedule Report Generator (SRG) are computer programs that manipulate data-base files in ways that are advantageous in scheduling. Originally designed for the Space Shuttle flight schedule, the program can be easily modified for other scheduling situations.

Schedule Organizer provides a simple method for generating distribution lists. These distribution lists contain readers' names for each task schedule defined by the input files. Schedule Tracker provides an effective method for tracking tasks that are "past due" and/or "near term." ST generates reports for each responsible staff member who has one or more assigned tasks that fall within the two listed categories. This enables an engineering manager to monitor tasks assigned to staff by running ST on a weekly basis. ST lists only reports on tasks that have become past due or are scheduled for completion in the near future.

Schedule Report Generator provides a simple method for generating periodic schedule reports. SRG enables an engineering manager to monitor tasks assigned to staff members on a weekly basis. SRG sorts three types of reports by use of one or more data fields as sorting keys. One type is sorted by use of the calendar year as the primary key and the end date as the secondary key. Another type is sorted by flight number. A third type of report, Waterfall plots, is also generated by SRG by use of the end date as the sorting key.

SRG requires as input a single file or two concatenated files that contain up to 400 single line entries. The user constructs the input file by using the LSE editor VAX utility prior to the execution of the program. The user can modify the current functional description text lines just displayed.

ST and SRG use the same data-base file as input. The common data-base file has a maximum number of 400 entries. The time span of all three programs is 19 months. Both of these maximum numbers can be modified by the user. SRG can be purchased separately or in a package (COSMIC program COS-10021) containing SO, ST, and SRG. SRG requires the VMS Operating System on a DEC VAX computer and was written in PL/1 and DEC Command Language (DCL). SRG was developed in 1984.

This program was written by Fernando F. Collazo of Rockwell International Corp. for **Johnson Space Flight Center.**
MSC-21527/TN

FOR ADDITIONAL INFORMATION

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Communication-Gateway Software for NETEX, DECnet, and TCP/IP

This software supports transfers of data between application programs on different computers.

The communications gateway software, GATEWAY, provides process-to-process communication between remote applications programs in different protocol domains. Communicating peer processes may be resident on any paired combination of NETEX, DECnet, or TCP/IP hosts. The gateway provides the necessary mapping from one protocol to another and facilitates practical intermachine communications in a cost-effective manner by eliminating the need to standardize on a single protocol or to implement multiple protocols in the host computers.

The purpose of the gateway is to support transfers of data between application programs on different host computers that use different protocols. The gateway computer must be physically connected to both host computers and must contain the system software needed to use the communication protocols of both host computers.

The process of communication between application partners can be divided into three phases: establishment of the session, transfer of data, and termination of the session. The communication protocols supported by GATEWAY have addressing mechanisms that enable an application to identify itself and distinguish among other applications on the network. The exact form of the address varies, depending on whether an application is passively offering (awaiting the receipt of a network connection from another network application) or actively connecting to another network.

When the gateway is started, GATEWAY reads a file of pairs of addresses. One of the addresses in a pair is used by GATEWAY for passively offering on one network while the other address in the pair is used for actively connecting on the other network, establishing the session. Now the two application partners can send and receive data in a manner appropriate to their home networks.

GATEWAY accommodates full duplex transmissions. Thus, if the application partners are sophisticated enough, they can send and receive simultaneously. GATEWAY also keeps track of the number of bytes contained in each transferred packet of data. If GATEWAY detects an error during the transfer of data, the sessions on both networks are terminated, and the passive offer on the appropriate network is reissued.

After performing the desired transfer of data, one of the remote applications sends a "network disconnect" to the gateway to close its communication link. Upon detecting this "network disconnect," GATEWAY replies with its own "disconnect" to ensure that the network connection has been fully terminated. Then GATEWAY terminates its session with the other application by severing the communication link.

GATEWAY has been implemented on a DEC VAX computer under VMS 4.7. It is written in Ada and has a central-memory requirement of approximately 406K bytes. The communications protocols supported by GATEWAY are Network Systems Corporation's Network Executive (NETEX), Excelan's TCP/IP, and DECnet. GATEWAY was developed in 1988.

This software was developed by B. Keith of **Goddard Space Flight Center** *and written by D. Ferry and E. Fendler of Computer Science Corporation. GSC-13236/TN*

FOR ADDITIONAL INFORMATION

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Electrotechnology

0122 Manufacturing Technology For Solid State Microwave Systems
0123 Repeater Fault Location in Wire Communication Systems (Licensing Opportunity)
0124 Broadband High Frequency Sky-Wave Antenna
0125 "Hotline" to Report on European Laws and Standards
0126 Less Expensive Voltage Standard Developed
0127 Symmetric Waveguide Junction Combiner (Licensing Opportunity)
0128 Automated Power-Distribution System—The system monitors and controls ac and dc electrical power to modular loads. (Licensing Opportunity)
0129 Concurrent Finite-Element Analysis on Hypercube Computers—A robust general approach requires minimal tailoring to specific cases.
0130 Binary Operation of a Liquid-Crystal Light Valve—Operating conditions that provide increased contrast have been discovered.

Testing & Instrumentation

0131 Current-Monitoring and -Limiting Circuit for 28-Vdc Supply—This circuit acts as a limiter, monitoring amplifier, and delayed-action circuit breaker.
0132 Dielectric Coating for Hot-Film Flow Sensors—A polymer/silica combination withstands cryogenic cycling. (Licensing Opportunity)
0133 High-Voltage Square-Wave Generator—Pulse rise times of the order of 50 ns are routine. (Licensing Opportunity)
0134 Low-Inductance Wiring for Parallel Switching Transistors—Transistors share current equally, without sacrifice of switching speed. (Licensing Opportunity)
0135 Noncoherent Combination of Optical-Heterodyne Outputs—Performance in the presence of atmospheric turbulence would be improved.
0136 Optical Pseudocolor Encoding of Gray-Scale Image—Optical encoding is much faster than is digital electronic encoding. (Licensing Opportunity)
0137 Study of Adaptive-Array Signal Processing—Techniques for the suppression of interference are compared.
0138 Temperature Dependence of Single-Event Effects—In most cases examined, vulnerability to these effects increased or remain constant with temperature.
0139 Two-Way Optical Data Link on One Fiber—Dual-purpose LED's reduce cost.

Testing & Instrumentation

0140 New Compact VISAR Interferometer Simplifies Operation
0141 Tracers Used to Locate Cable Leaks
0142 Infrared Wavelength Measuring Device Developed
0143 Novel Device Measures a Variety of Electrical Pulses
0144 Viewing Integrated-Circuit Interconnections by SEM—Back-scattering of energetic electrons reveals hidden metal layers.

Other Items of Interest

0216 Inexpensive Frequency Calibration Service Available

Manufacturing Technology For Solid State Microwave Systems

Westinghouse Electric Corporation established and validated manufacturing techniques for cost effective, high volume gallium arsenide (GaAs) monolithic microwave integrated circuit (MMIC) and discrete device fabrication. The project team, headed by Westinghouse, includes three systems houses, a leading device manufacturer, a materials supplier, and a polishing and materials characterization specialist. Contractors are Westinghouse, TRW, Rockwell International, Avantek, Johnson Matthey, Aracor, and Varian Associates.

The companies fabricated 12 different microwave device types: power, gain, low noise, and diode devices applicable to radar, electronic warfare (EW), and communication systems.

The 12 devices were fabricated on five different types of GaAs semi-insulating material, using ion implantation techniques. After the devices were fabricated on approximately 1000 three-inch GaAs wafers, the electrical characteristics and yields were analyzed. Comparisons of the results of the five material types have been made to determine material and/or device correlations. These devices have been incorporated into radar, EW, and communications demonstration modules.

In addition to the device and module fabrication efforts, the companies placed significant emphasis on the wafer preparation and materials and the device characterization aspects of MMIC fabrication.

Wafer sawing and polishing methods also were evaluated. The efforts resulted in an improved polishing technique for GaAs wafers, which significantly reduces the surface and subsurface damage observed in the substrate material. The improved polish technique increased the percentage yield for die and wafer. The technique has been transferred to the Johnson-Matthey baseline process, and the details of the technique are available for industry application. Although not implemented in this program, the wafer sawing techniques that have been evaluated produce a preferred sawing technique, that is, usage of a multiwire saw with an abrasive slurry. Nondestructive evaluation of the starting and processed wafers also was studied in detail.

The companies have evaluated the following techniques and recommend them for industry applications: contactless mobility, photon backscattering, surface photovoltage, low penetration X-ray diffraction, electron channeling, EL2 testing, frametape mounting, and test element groups for evaluation of fabricated devices. The RF on-wafer testing significantly decreased the time and cost involved in the electronic testing of devices. It used to take several hours for dicing, mounting, lead bonding, and testing of a wafer on devices, but now it takes 45 minutes for each wafer (122 die sights a wafer). The automatic test has replaced the manual and a sometimes destructive test method and, therefore, increases die-to-wafer yield. The frame-tape mounting facilitated rapid testing of diced components at TRW where on-wafer testing was not available. The FET yield improved 5 to 30 percent. The two-step polishing technique reduced the wafer surface damage index by a factor of 10. All of the data collected for this program are available in a computerized data base established at Westinghouse.

FOR ADDITIONAL INFORMATION: To discuss this effort further, contact: Project Engineer: Wallace C. Patterson, Air Force Manufacturing Technology Program, ATTN: AFWAL/WRDC/MTEC, Wright Patterson AFB, OH 45433-6533; (513)255-2461. Refer to contract: F33615-85-C-5064.

U.S. Army Fact Sheet

Repeater Fault Location in Wire Communication Systems

An invention was made with which the location of faulty or inoperative repeaters in a wire communication system can be detected. It is a novel method of locating a faulty repeater in a system which includes a plurality of unattended repeaters. The method provides the means by which the location of an inoperative unattended repeater may be quickly and accurately pinpointed by measurements made at one of the attended terminals of the system.

The method has been laboratory proven and field tested for use by the United States Army.

The invention can be used for the maintenance and repair of unattended terminals within a wire or cable communication system or network which includes a great many terminals. It is most useful by providing a simple and easily operated circuitry for accurately locating faulty unattended repeaters on a transmission line in which the power for operating said repeaters over the same line or cable which carries the information.

Patent status: U.S. Patent Number 3,297,833.

FOR ADDITIONAL INFORMATION: Charles Grzenda, Chief, Office of Research and Technology Applications, Center for C3 Systems, Attn: AMSEL-RD-C3-PB, Fort Monmouth, NJ 07703; Telephone: (201)544-3119. Refer to technology application No. 3.

U.S. Army Fact Sheet

Broadband High Frequency Sky-Wave Antenna

A new invention created a broadband, high frequency (HF), directional, sky-wave antenna design that is physically small compared to the current log periodic type broadband HF sky-wave antennas.

The invention has been laboratory proven and is being considered for possible commercial applications.

The present invention can be used with any HF communications systems. The primary objective is to provide a sky-wave antenna that is relatively small, light weight, inexpensive and easy to deploy. The antenna is most useful in communication systems designed for restoration applications or within transportable systems.

Patent status: U.S. Patent Number 4,733,243.

FOR ADDITIONAL INFORMATION: Charles Grzenda, Chief, Office of Research and Technology Applications, Center for C3 Systems, Attn: AMSEL-RD-C3-PB, Fort Monmouth, NJ 07703; Telephone: (201) 544-3119.

NIST Technology Update

National Institute of Standards & Technology

U.S. Department of Commerce, Gaithersburg, MD 20899

'Hotline' to Report on European Laws and Standards

Exporters, manufacturers, standards organizations, and others concerned about trade with the European Community (EC) may now telephone a recorded "hotline" message on draft EC laws and standards that might create technical trade barriers. The hotline reports on proposed laws in the form of directives and standards being developed by the EC and its two major standards development organizations in Brussels: the European Committee on Standardization and the European Committee for Electrotechnical Standardization. Proposed standards also are reported from the European Telecommunications Standards Institute, which is working to unify the European telecommunications system. Hotline topics are listed by subject area and product. Information is provided on deadlines for comments, and a point of contact for obtaining a review copy of the text is given.

FOR ADDITIONAL INFORMATION: The hotline can be reached by calling (301)921-4164. It is updated weekly.

NIST Technology Update

National Institute of Standards & Technology
U.S. Department of Commerce, Gaithersburg, MD 20899

Less Expensive Voltage Standard Developed

A precise voltage is generated when microwave radiation is applied to a Josephson junction (two layers of superconducting material separated by a thin-film insulator). NIST researchers pioneered the development of voltage standards based on large arrays of superconducting Josephson junctions. Since 1984 more than 20 national, military, and industrial standards laboratories have implemented Josephson array voltage standards. Until recently, however, the designs required a high microwave operating frequency (70-100 GHz) to achieve stable operation. This increased the cost of standards, slowing their wider use in secondary calibration laboratories. Now, NIST scientists, working with colleagues at Quantum Magnetics of San Diego, Calif., under a cooperative research and development agreement, have developed a successful design at an operating frequency of 24 GHz where there are many commercial applications. The cost of the system has therefore been reduced substantially.

FOR ADDITIONAL INFORMATION: Paper no. 43-90, which describes this development, is available from Jo Emery, Div. 104, NIST, Boulder, Colo. 80303; 303/497-3237.

U.S. Navy Fact Sheet

Licensing Opportunity

Naval Weapons Center

Symmetric Waveguide Junction Combiner

This invention pertains to the fields of wave transmission lines, oscillators, and amplifiers. More particularly, the invention pertains to plural, parallel connected, transistor oscillators linked by a cavity. The symmetric waveguide junction exhibits several properties derived from its unique symmetry that make it a versatile modular component for building high-power or high-frequency microwave or millimeter RF sources.

This invention involves a waveguide junction power combiner of generally cubic symmetry with six rectangular waveguide ports extending from a spherical combining region in three pairs aligned with mutually orthogonal diameters of the region. Since the combiner is symmetrical, since the ports are well isolated, and since there are no planar surfaces and a minimal number of edges in the combining region, minimal reflections exist within and from the combining region; these reflections interfere with port isolation and create frequency-dependent effects. As a result, no circulator is required at any port of the combiner. Because frequency dependence effects are minimized, the combiner has a wide bandwidth and its inputs do not require tuning, which might affect connected devices and reduce bandwidth.

Patent Number 4,853,650

FOR ADDITIONAL INFORMATION: Charles T. Newmyer (Code 374), Naval Weapons Center, China Lake, CA 93555-6001; (619)939-1074.

NASA Tech Brief
National Aeronautics and Space Administration
Marshall Space Flight Center, Alabama

Licensing Opportunity

Automated Power-Distribution System

The system monitors and controls ac and dc electrical power to modular loads.

An automated power-distribution system monitors and controls electrical power to modules in a network. The system handles both 208-V, 20-kHz single-phase alternating current and 120- to 150-V direct current. Potential applications include autonomous land vehicles and automated industrial process systems.

The power-distribution system needs minimal attention. It can detect faults and protect against them, in addition to switching and monitoring loads.

The system (see figure) includes the following:

- Switchgear interface controllers (SIC's),
- Generic controllers (GC's),
- Analog-to-digital cards (ADC's),
- Remote bus isolators (RBI's),
- Remote-controlled circuit breakers (RCCB's),
- Remote power controllers (RPC's), and
- Various monitoring circuits.

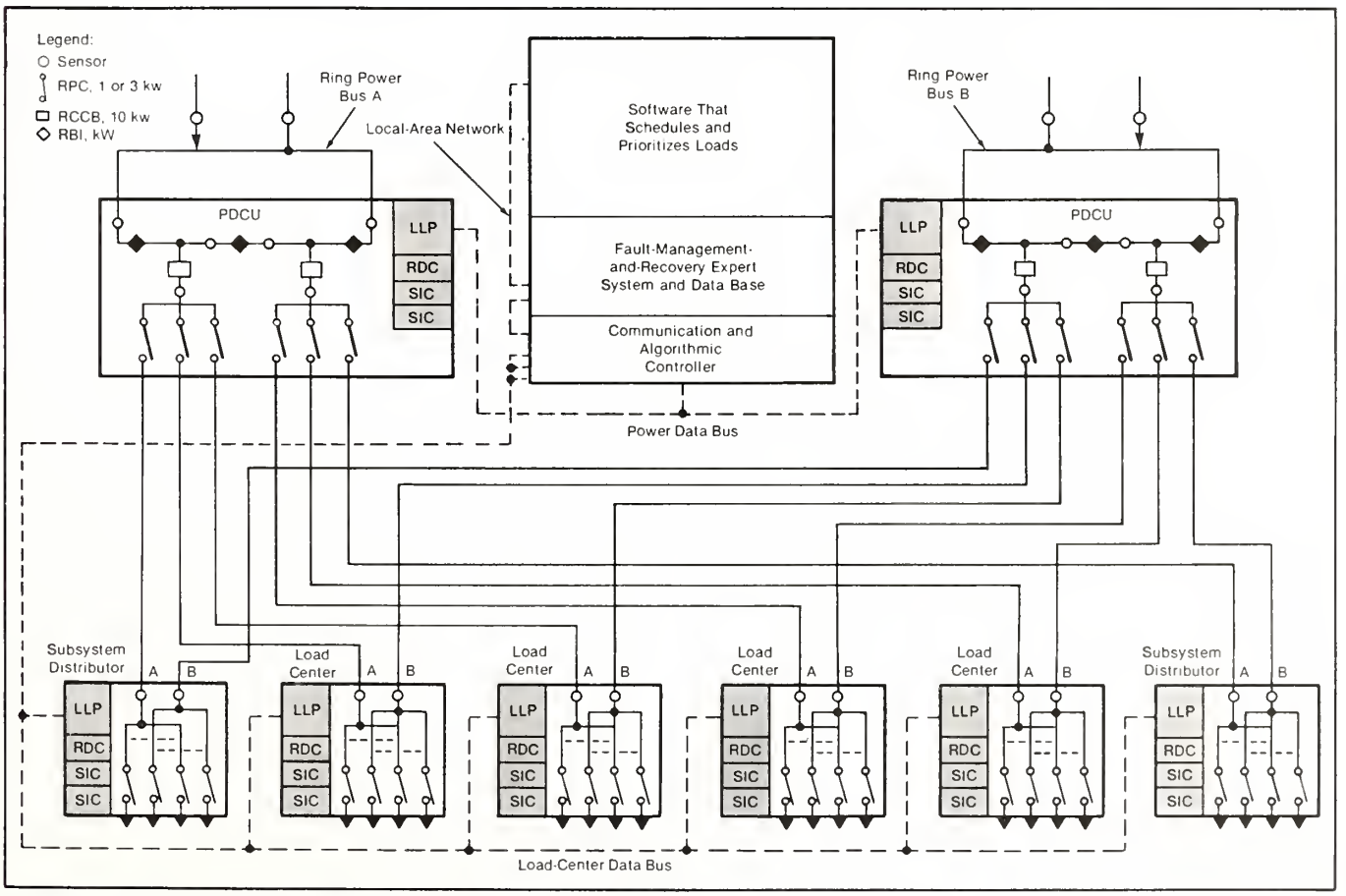
An SIC processes 19 different commands from a lowest level processor (LLP) and returns response data. It communicates with 14 GC cards, each of which controls and monitors an RBI, an RCCB, or an RPC. It also communicates with an ADC, from which it receives 16 voltage, current, and temperature signals from sensors. The SIC processes all this information in an 8-bit microprocessor programmed via an electrically programmable read-only memory (EPROM).

A GC card decides, on the basis of the information it receives from its SIC, whether to turn a switch on or off, depending on whether the information indicates an undervoltage, overcurrent, surge current, ground fault, or overtemperature condition. It sends the SIC serial data indicating its decision.

An ac RPC is an alternating-current-switching circuit that includes a magnetically latching relay, a main solid-state switch, and a parallel current-limiting switch. It also includes fast-trip circuitry, analog sensors, power supplies, and switch-status output circuitry.

A dc RPC includes a number of parallel solid-state switches controlled by a closed-loop control system that limits current automatically in case of a fault. Like an ac RPC, it provides sensor and switch-status outputs.

An ac RCCB is an alternating-current device that supplies 10 kW at 208 V, 20 kHz, to as many as three RPC's. It includes a large relay that switches both sides of the 20-kHz line. A dc RCCB includes solid-state switches in parallel, sensor and switch-status outputs, and both overcurrent- and un-



Power Is Distributed to Load Modules from power-distribution control units (PDCU's) via subsystem distributors. Ring busses carry power to the PDCU's from the power source.

dervoltage-shutoff circuitry.

RBI's carry power to the RCCB switches. An RBI includes a large relay that switches both the positive and return sides of the powerline. It provides the GC card with relay-status information only, and can be switched only when the input power is off.

ADC's convert analog signals from sensors into 8-bit digital signals. They transmit, to the SIC's, digitized data on voltages, currents, powers, power factors, and temperatures.

The system responds quickly to faults. For example, it responds to a 175-percent overcurrent with a 1-μs initial reaction and a 15- to 50-ms settling time, or to a 125°C over temperature in 50 ms.

This work was done by Cindy Thomason of **Marshall Space Flight Center** *and Paul M. Anderson and James A. Martin of Martin Marietta Corp.*

Inquiries concerning rights for the commercial use of this invention should be addressed to the Patent Counsel, Marshall Space Flight Center. Refer to MFS-28440/TN.

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REFER TO THE NUMBER LISTED AT THE END OF THIS ARTICLE

NASA Tech Brief
National Aeronautics and Space Administration
NASA's Jet Propulsion Laboratory, Pasadena, California

Concurrent Finite-Element Analysis on Hypercube Computers

A robust general approach requires minimal tailoring to specific cases.

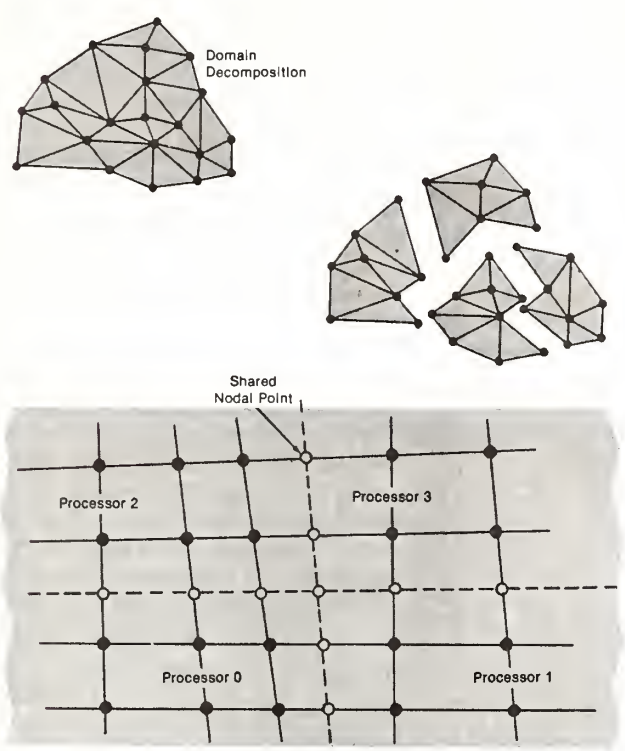


Figure 1. The **Computational Domain** is decomposed into subdomains, each assigned to one processor. Some nodal points fall on boundaries between subdomains and are shared by the adjacent processors.

An improved approach to the execution of finite-element codes on hypercube and similar concurrent data processors increases the efficiency of computation for many different types of problems. The approach is based on a flexible general model of computation on, and communication among, large-node parallel processors.

Merely mapping a serial finite-element-method code onto a system of parallel processors is a straightforward undertaking in which the computational domain is decomposed into subdomains or nodes that contain contiguous finite elements, each subdomain being assigned to one of the processors (see Figure 1). In the general model, the information relevant to the degrees of freedom or matrix elements of a node resides in the local memory of the proccessor assigned to the given subdomain. A given processor has direct access only to its "own" information and can be thought of as solving a smaller version of the original full problem, subject to some special boundary conditions. The various processors communicate with each other to exchange the boundary information and obtain a global solution. The problem is to devise a mapping that increases the speed of computation by decreasing the amount of necessary communication among processors.

One conventional approach to the solution of the domain-decomposed problem involves direct methods (e.g., variants of Gaussian elimination), which are robust but can be too expensive for systems of large rank and bandwidth, such as arise from large three-dimensional domains. Another conventional approach involves iterative methods [e.g., the preconditioned-conjugate-gradient (PCG) method], which require less communication than direct methods do but are not robust, in the sense that their convergence properties are highly problem-dependent and difficult to guarantee.

The new approach is a hybrid that combines direct methods within the subdomains and PCG iteration on the remaining boundary system to obtain a method of solution that is both robust and efficient. In the iterative component of the method, the rank of the system is a small fraction of the rank of the full unreduced system; this feature enhances the convergence of the

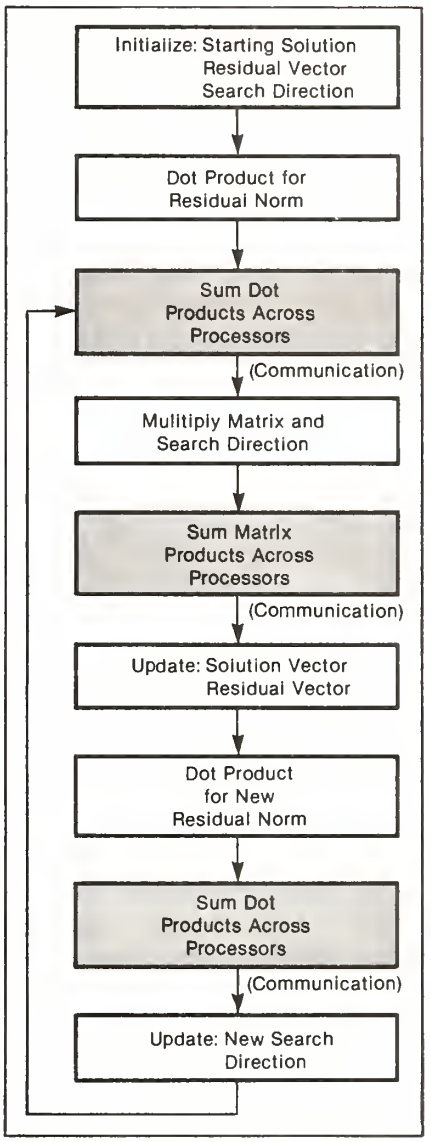


Figure 2. The **Preconditioned-Concurrent-Gradient Algorithm** is modified for the new concurrent finite-element method by the addition of the shaded steps. These steps include the communication tasks, which contain all the machine-specific interprocessor activity and which are isolated from the familiar calculation tasks. The equivalent sequential procedure is recovered by simply deleting the shaded steps.

PCG iteration. In the direct component of the method, the cost is only that of the reduction of small subdomains. Therefore, if the number of processors is increased in direct proportion to the size of the problem, the cost associated with elimination remains constant, in contrast with the cost of an elimination-only scheme, which cost would increase more steeply than in simple proportion to problem size.

The new approach preserves the general structure and function of conventional sequential finite-element-method software (see Figure 2). It may be regarded as a model for the construction of the next generation of finite-element analysis packages capable of exploiting computers of parallel architecture. It can be generalized to both distributed- and shared-memory multicomputers, thus eliminating a degree of machine specificity that might otherwise restrict its general usefulness.

This work was done by G.A. Lyzenga and A. Raefsky of Caltech and B. Nour-Omid of Lockheed Palo Alto Research Laboratory for **NASA's Jet Propulsion Laboratory**. *NPO-17602/TN*

FOR ADDITIONAL INFORMATION: *Contact: Director, Technology Transfer Division, P.O. Box 8757, BWI Airport, MD 21240; (301) 621-0100 Ext. 241*

REFER TO THE NUMBER LISTED AT THE END OF THIS ARTICLE

NASA Tech Brief
National Aeronautics and Space Administration
NASA's Jet Propulsion Laboratory, Pasadena, California

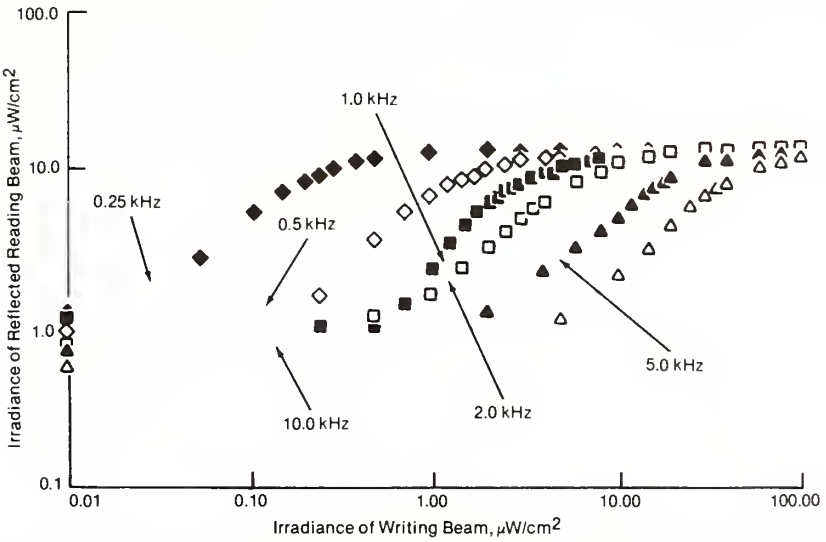
Binary Operation of a Liquid-Crystal Light Valve

Operating conditions that provide increased contrast have been discovered.

Conditions for the operation of a commercially available liquid-crystal light valve as a binary spatial light modulator have been discovered. In this mode, the modulator turns on sharply and then saturates as the intensity of the writing beam increases. Potential applications include the enhancement of images, optical recording, and holography.

The light valve comprises a photoconductive layer and a liquid-crystal layer that are separated by a dielectric mirror and sandwiched between two transparent electrodes. The liquid-crystal molecules have a 45° twist in going from one side of the cell to the other. The orientation of the molecules at the faces is maintained by grooves scribed on the materials at the boundaries of the liquid-crystal layer.

The photoconductor and liquid-crystal layers act as a voltage-divider network. When no light falls on the photoconductor, its resistance is high, so that when an ac voltage is applied across the entire package, the greater fraction of the voltage appears across the photoconductor. Wherever the writing beam illuminates the photoconductor, its electrical resistivity decreases, allowing a greater fraction of the applied voltage to appear across the liquid-crystal layer in the illuminated regions. The increased voltage across the liquid-crystal layer changes the twist and tilt of the liquid-crystal molecules, altering the birefringent properties of the layer. A polarized reading beam incident on the liquid-crystal layer is reflected back by the dielectric mirror. The polarization of the reflected beam depends on the state of the liquid crystal. The reflected beam is analyzed by a polarizer.



The Transfer Function of the Liquid-Crystal Light Valve shifts as the frequency of the ac bias voltage is changed. The maximum slope occurs at a bias frequency of 1 kHz.

The reflected beam can be separated from the incident reading beam either by using beam splitters or by operating at a nonnormal angle of incidence.

In experiments, the writing beam was obtained by filtering the output of an air-cooled argon laser to select the 514.5-nm-wavelength output. A helium/neon laser produced the reading beam. High contrast was achieved with writing-beam intensities that ranged from $\lesssim 0.4$ to $\gtrsim 4$ $\mu W/cm^2$ at a 1-kHz bias of 7.07 Vrms. Operating parameters that were altered to optimize performance for use as a binary modulator include the frequency and amplitude of the ac bias voltage and the orientations of the polarizers in the reading beam.

The family of curves in the figure shows how the intensity of the reflected light in the experiments varied as the frequency of the bais voltage was varied in the vicinity of the optimum operating point for use as a binary modulator. For each curve, the angle of the analyzing polarizer was adjusted to maximize reflectivity at a writing intensity of 100 $\mu W/cm^2$. It is expected that the optimum operating parameters will differ somewhat from one modulator to another. However the qualitative features should be similar.

This work was done by Jeffrey A. Davis of San Diego State University Foundation for **NASA's Jet Propulsion Laboratory.** *NPO-17614/TN*

FOR ADDITIONAL INFORMATION: *Contact: Director, Technology Transfer Division, P.O. Box 8757, BWI Airport, MD 21240; (301) 621-0100 Ext. 241*
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NASA Tech Brief
National Aeronautics and Space Administration
Goddard Space Flight Center, Greenbelt, Maryland

Current-Monitoring and -Limiting Circuit for 28-Vdc Supply

This circuit acts as a limiter, monitoring amplifier, and delayed-action circuit breaker.

A current-monitoring and -limiting circuit protects a 28-Vdc power supply against a steady overload. In addition, it provides some protection against sudden peak currents — especially the large inrush current that would otherwise occur when a dc-to-dc converter or other load containing a capacitance is suddenly connected to the power supply via a manual or mechanical relay switch. It is desirable to suppress large inrush currents because they can cause electromagnetic interference in other circuits and can stress the switch contacts.

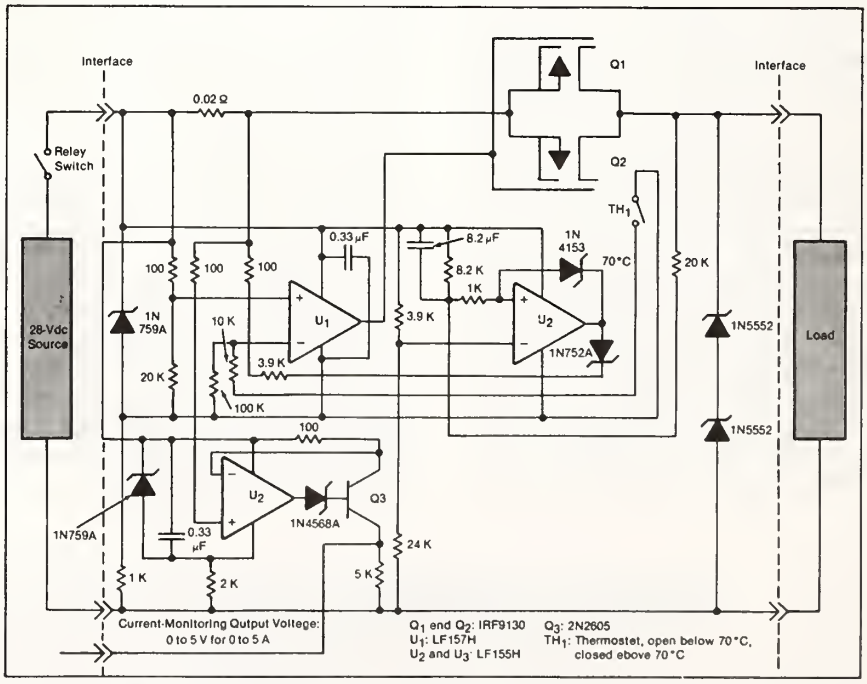
The current-limiting element in this circuit consists of a pair of power metal oxide/semiconductor field-effect transistors (MOSFET's). The development of such devices has progressed to a stage at which they are attractive for use in inrush-current-suppressing applications. By taking advantage of their low "on" resistances and their low required drive powers, one can obtain a circuit that has low insertion resistance and that limits current to the load. To limit the current by use of conventional bipolar transistors, one would have to provide for standby power to ensure the saturation of such transistors to maintain a low voltage drop across them. The use of the MOSFET's in this circuit reduces the required standby power. Furthermore, the MOSFET's chosen for this circuit are of the p-channel type, which are easy to bias.

As shown in the figure, the two p-channel power MOSFET's, Q_1 and Q_2, are connected in parallel to handle the desired maximum current of 3 A. A small precise wirewound resistor of 0.02 Ω is used to sense the current for both the control and the monitoring functions. The current-sensing voltage developed across this resistor is sensed by the operational amplifier U_1 and compared with a reference voltage developed by the voltage divider of 100 Ω and 20 kΩ across zener diode 1N759A. If the current-sensing voltage equals or exceeds the reference voltage, the drive to Q_1 and Q_2 is reduced until the current-sensing voltage equals the reference voltage. This condition of equality corresponds to a load current of approximately 3 A.

When the current is less than the 3-A maximum, Q_1 and Q_2 are biased "on" and present a low insertion resistance between the source and the load. Because Q_1 and Q_2 dissipate considerable power in the current-limiting mode, either they have to be mounted on a heat sink capable of dissipating this power, or they must be turned "off" when a predetermined safe operating temperature is reached. For this purpose, the temperature of Q_1 and Q_2 is assumed to be that of the heat sink and is sensed by thermostat TH_1 mounted on the heat sink. TH_1 is set to switch, when the temperature rises above 70 °C, to alter the voltage applied to the inverting input of U_1 in such a way as to cause Q_1 and Q_2 to turn off.

In the event the load resistance is such that the output voltage is less than approximately one-half of the input voltage, the circuit behaves as a circuit breaker that has a fixed delay. For this purpose, the voltage across Q_1 and Q_2 is sensed by operational amplifier U_2, which is configured as a comparator. The delay makes it possible to charge a capacitance of reasonable size in or across the load without turning "off" prematurely. The voltage across the 0.02-Ω resistor is also sensed by operational amplifier U_3 and transferred with reference to the common return via transistor Q_3 and the collector resistor of 5 kΩ, giving a current-indicating output potential that ranges from 0 to 5 V when the current ranges from 0 to 5 A.

This work was done by G. Ernest Rodriguez of **Goddard Space Flight Center.** *No further documentation is available. GSC-13310/TN*



The **Current-Monitoring and -Limiting Circuit** limits the steady load current to 3 Adc, provides delayed protection against overloads, and puts out a current-monitoring voltage signal.

FOR ADDITIONAL INFORMATION: *Contact: Director, Technology Transfer Division, P.O. Box 8757, BWI Airport, MD 21240; (301) 621-0100 Ext. 241*
REFER TO THE NUMBER LISTED AT THE END OF THIS ARTICLE

NASA Tech Brief
National Aeronautics and Space Administration
Langley Research Center, Hampton, Virginia

Licensing Opportunity

Dielectric Coating for Hot-Film Flow Sensors

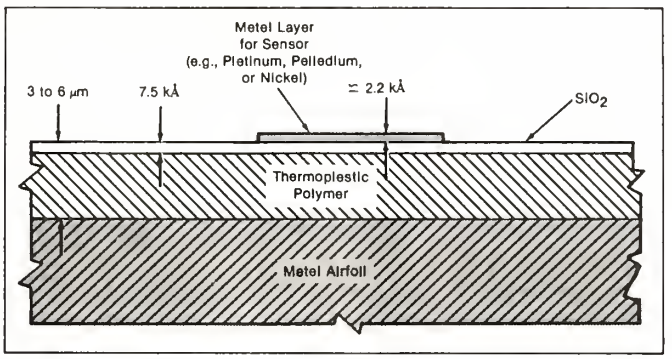
A polymer/silica combination withstands cryogenic cycling.

With the very thin boundary layers and cryogenic temperatures encountered in the National Transonic Facility (NTF), conventional sensors are not acceptable for the detection of transitions in flows. Typically, hot-film sensors used to detect transitions are deposited on substrate materials, and the substrates are attached to airfoils. The substrates contribute to the roughnesses of surfaces and can cause boundary-layer transitions.

A very-thin-film dielectric coating that is stable over a range of temperatures has been developed to satisfy several criteria for the NTF. This dielectric coating, a combination of fused silica and a thermoplastic polymer, has sufficient stability to withstand the stresses placed upon it by cycling to and from cryogenic temperatures. The coating can be tailored to meet almost any criterion of roughness height.

First, the airfoil is coated (see figure) with a vapor-deposited thermoplastic polymer to a thickness of approximately 3 to 6 μm. Next, a layer of fused silica (SiO_2) is vapor-deposited to a thickness of 7.5 kÅ by electron-beam evaporation with simultaneous bombardment by a beam of ions. Then metal layers used for sensors are electron-beam-evaporated directly onto the dielectric coating.

The commercial thermoplastic polymer used was chosen because of its excellent electrical and mechanical properties and the fact that it can be deposited from a vapor uniformly over large areas without the formation of pinholes. It has a high percentage of elongation to break that accommodates the different linear coefficients of expansion of the three major components: the stainless-steel airfoil, the polymer, and the fused silica. Because of its flexibility, the polymer is not an acceptable substrate for such vapor-deposited metals as platinum, palladium, and nickel, commonly used for hot-film sensors. These metals, when vapor-deposited, have intrinsic stresses in the films, and the polymer surfaces yield to the film stresses at the interfaces with the metals, causing fractures in the films.



Both the Polymer and the Fused Silica are vapor-deposited directly onto the metal airfoil.

SiO_2 was chosen because it is a very thermally and chemically stable oxide and is easily vapor-deposited. Therefore, the SiO_2 layer is incorporated as a buffer between the polymer and metal films.

Hot-film devices have been fabricated on this thin-film dielectric layer and tested with good results. This technique should prove potentially useful for research in the application of hot-film sensors to airfoils.

This work was done by Purnell Hopson, Jr., and Sang Q. Tran of **Langley Research Center**. *No further documentation is available.*

This invention is owned by NASA, and a patent application has been filed. Inquiries concerning nonexclusive or exclusive license for its commercial development should be addressed to the Patent Counsel, Langley Research Center. Refer to LAR-13678/TN.

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NASA Tech Brief
National Aeronautics and Space Administration
NASA's Jet Propulsion Laboratory, Pasadena, California

Licensing Opportunity

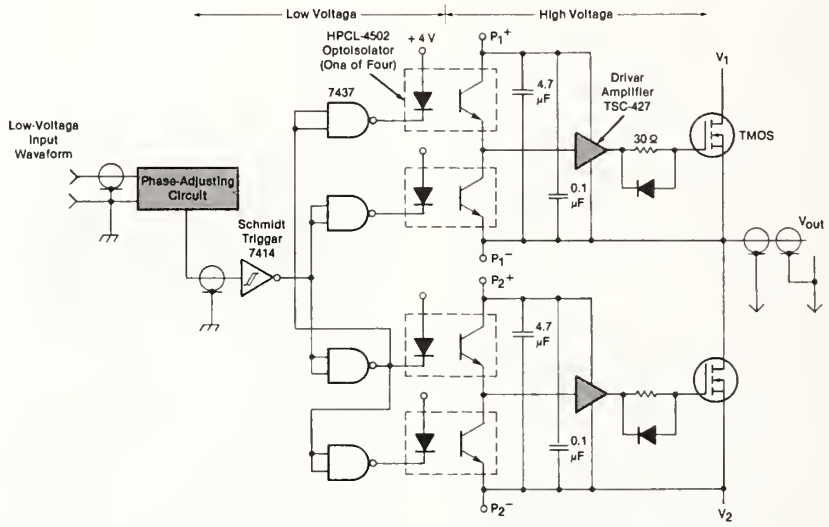
High-Voltage Square-Wave Generator

Pulse rise times of the order of 50 ns are routine.

A fast switching circuit puts out rectangular pulses of the order of a kilovolt or greater at typical repetition frequencies as high as hundreds of kilohertz and with rise times as short as 50 ns. The circuit is designed around power metal oxide/semiconductor field-effect transistors (MOSFET's) that are capable of blocking potentials up to 1,000 V. The design overcomes the limitations on switching speeds imposed by the combination of junction capacitances and collector resistors in bipolar-transistor switching circuits. The switching circuit could be used, for example, to supply power to a pulsed laser or to modulate a beam of charged particles in a laboratory experiment or industrial process.

The circuit (see figure) features two power MOSFET's on the high-voltage side, optically isolated from the low-voltage side. The controlling input waveform from a low-voltage (typically, 5 V for transistor/transistor logic) pulse generator is fed through a circuit that adjusts the phase, if necessary for the specific application. A Schmitt trigger cleans up any noise on the signal and directs the waveform to the NAND gates, which drive the light-emitting diodes (LED's) of the optoisolators. When a NAND output goes low, current passes through and activates the associated LED, turning on the associated power MOSFET switch. The transistor-switch side of the optoisolators, and everything else from there to the final output floats on the high voltages that are used in forming the final wavetrain.

Power rails P_1 and P_2 are on 12-Vdc power-supply circuit cards that are floated by use of an isolation transformer. The return (negative) side of each such 12-Vdc supply floats on the source line of its associated power MOSFET. Each 12-Vdc card supplies power to its optoisolator switch and to an integrated-circuit noninverting driver amplifier capable of charging 1,000 pF in 30 ns. This amplifier promotes high switching speed by rapidly charging the gate capacitance of its associated power MOSFET. To guarantee low supply impedance over a wide frequency range, a tantalum capacitor in parallel with a ceramic capacitor is used to bypass the supply to the driver.



Optically Isolated Power MOSFET's in Series rapidly switch the output between high voltages V_1 and V_2.

The optoisolator switches in each pair are arranged in series "totem-pole" configuration to switch the driver amplifier between the source line, *S*, of the associated power MOSFET and *S* + 12 volts. The two power MOSFET's are also configured in "totem-pole" fashion to drive the output load between V_1 and V_2, the high voltages used in the final wavetrain. The "totem-pole" network enables the n-channel MOSFET's to switch between arbitrarily chosen, variable voltages, as long as $V_1 > V_2$. (V_2 can be negative.)

This work was done by Mark T. Bernius and Ara Chutjian of Caltech for **NASA's Jet Propulsion Laboratory.**

This invention is owned by NASA, and a patent application has been filed. Inquiries concerning nonexclusive or exclusive license for its commercial development should be addressed to the Patent Counsel, NASA Resident Office-JPL. Refer to NPO-17772/TN.

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NASA Tech Brief
National Aeronautics and Space Administration
Marshall Space Flight Center, Alabama

Licensing Opportunity

Low-Inductance Wiring for Parallel Switching Transistors

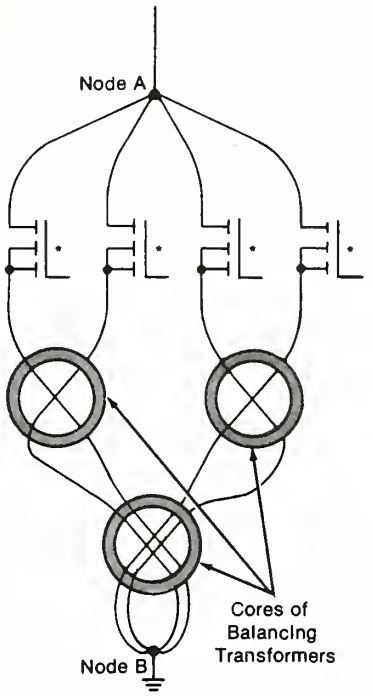
Transistors share current equally, without sacrifice of switching speed.

A simple configuration for the wiring of multiple parallel-connected switching transistors minimizes the stray wiring inductance while providing for the use of balancing transformers, which equalize the currents in these transistors. The balancing of currents is necessary to prevent overloads in individual transistors, and the minimization of inductance is essential for fast switching of high currents. High-current transistor switches that could benefit from the new configuration are found in controllers for brushless motors, dc-to-dc voltage converters, controllers for electric furnaces, remote controllers for dc power, high-power pulse generators, and driving circuits for traction motors.

Interleaving and multifilar windings can reduce the leakage inductances of transformers to acceptable levels. Previously, however, the use of balancing transformers entailed excessive distributed wiring inductances because the connections to the transistors were made with relatively-high-inductance single wires (see Figure 1).

The new configuration (see Figure 2) is based on the established technique of reducing of inductance by laying wires in twisted pairs. The source and drain leads of each transistor are connected to six twisted pairs of wires. (To enhance clarity, Figure 2 shows only one pair, untwisted, connected to each transistor.) The twisted pairs from all the transistors are woven through the cores of the balancing transformers in a way that produces opposing magnetic fluxes, which minimize both the net inductance and the imbalances of currents.

This work was done by M.S. Veatch and D.M. Landis of Martin Marietta Corp. for **Marshall Space Flight Center.**



* Metal-Oxide/Semiconductor Field-Effect Transistor Switches

Figure 1. In the **Old Wiring Configuration**, currents are balanced on single wires, with return current running elsewhere. This configuration has relatively high inductance.

Inquiries concerning rights for the commercial use of this invention should be addressed to the Patent Counsel, Marshall Space Flight Center. Refer to MFS-28387/TN.

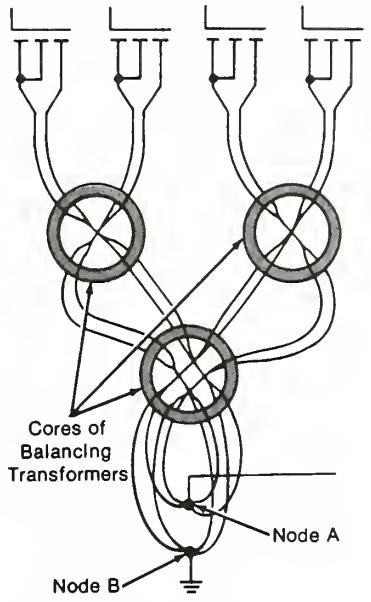


Figure 2. In the **New Wiring Configuration**, currents are balanced on twisted pairs of wires. Because the twisted pairs carry both the "hot-side" and return currents, this configuration has relatively low inductance.

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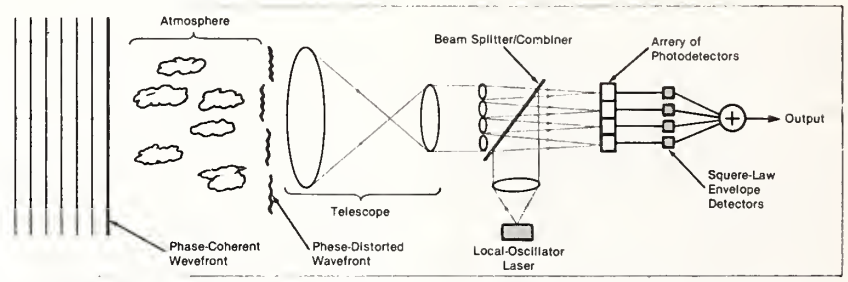
NASA Tech Brief
National Aeronautics and Space Administration
NASA's Jet Propulsion Laboratory, Pasadena, California

Noncoherent Combination of Optical-Heterodyne Outputs

Performance in the presence of atmospheric turbulence would be improved.

In a proposed scheme for the reception of amplitude- or frequency-modulated signals transmitted optically through the atmosphere, the main receiver aperture would be divided into subapertures equipped with receivers, and the outputs of the receivers would be combined noncoherently. Although this scheme is not optimal in the ideal case of a planar, coherent incident wavefront and precisely fabricated, diffraction-limited, large-aperture receiver optics, it can offer superior performance in the presence of a distorted wavefront and/or imperfect receiver optics.

In the ideal case, the best performance is obtained when the incident light is collected by a single, large-aperture telescope or other optical system that focuses the light onto a single heterodyne receiver; this depends on accurate matching of the wavefronts of the incoming and local-oscillator signals. However, in the nonideal case, it is difficult to match the wavefronts adequately in a receiver of large aperture, because it is difficult to fabricate a high-quality optical surface of large aperture. Furthermore, the refractive effects of atmospheric turbulence can cause random fluctuations in the phase and amplitude of the signal, resulting in destructive interference between portions of the wavefront that arrive at the receiver from different parts of a large aperture. Thus, in the nonideal case, the performance of a receiver does not improve when the aperture is enlarged beyond a size related to the scale of the imperfections.



Multiple Subaperture Receivers would be used instead of attempting to focus all the light from a single large aperture onto one receiver. The outputs of the receivers would be combined after demodulation. This system would not perform as well as a fully coherent system would, but could surpass a single-large-aperture system in the presence of atmospheric turbulence.

Each subaperture receiver in the proposed scheme would include combination with a heterodyne local oscillator and the output focused on a photodetector. The intermediate-frequency output of the photodetector would be demodulated noncoherently by a square-law envelope detector. The outputs of the envelope detectors would be summed to obtain the final receiver output (see figure).

Theoretical analyses and Monte Carlo simulations have been performed to quantify the relative advantages and disadvantages of the single, diffraction-limited, large-aperture scheme and the multiple-subaperture, noncoherent-combining scheme. The analyses show that in the absence of atmospheric turbulence, the signal-to-noise ratio of a noncoherent-combining system would typically be 15 to 25 dB below that of the single-aperture system. However, when atmospheric turbulence is taken into account, the performance of the single-aperture system would be limited by the sizes of the phase-coherence cells of the atmosphere. In that case, the noncoherent-combining scheme should be considered. For a given overall collecting-aperture area, the receiver would be optimized by making the diameter of each subaperture equal to the phase-coherence length of the atmosphere.

This work was done by Chien-Chung Chen and James R. Lesh of Caltech for **NASA's Jet Propulsion Laboratory.**
NPO-17693/TN

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NASA Tech Brief
National Aeronautics and Space Administration
NASA's Jet Propulsion Laboratory, Pasadena, California

Licensing Opportunity

Optical Pseudocolor Encoding of Gray-Scale Image

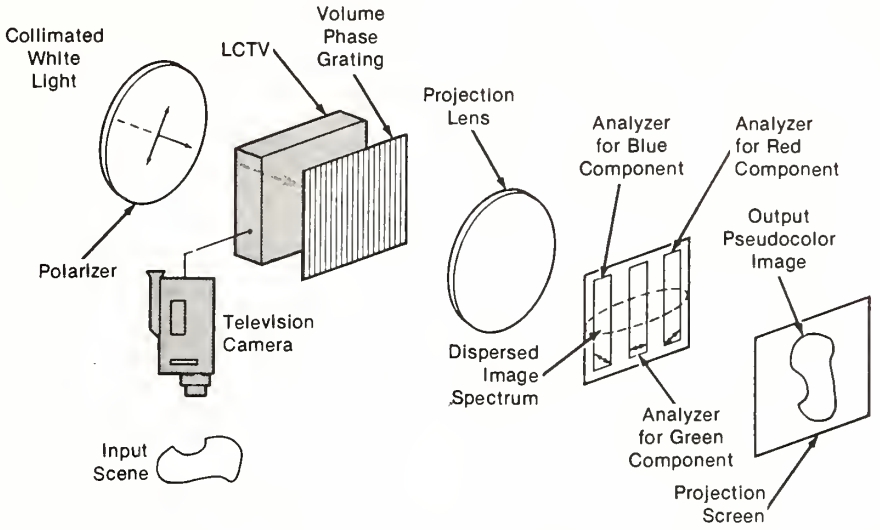
Optical encoding is much faster than is digital electronic encoding.

An experimental optical apparatus encodes a gray-scale image in pseudocolor. For such purposes as thermography, inspection of circuit boards, mammography, and mapping, it is advantageous to convert gray-scale images to pseudocolor because people can easily distinguish several thousand colors, whereas they can distinguish only about 20 shades of gray. Usually, pseudocolor is generated from gray by digital computer processing, which can impose significant delay between the reception and the display of the image. In contrast, the speed of the optical pseudocolor-encoding apparatus is limited only by the speed of the display device in it.

The apparatus (see figure) includes a liquid-crystal television display device (LCTV) without the usual attached polarizing screens. The LCTV is illuminated from behind by white light through an external polarizer. The polarization of light emerging from the LCTV is rotated from a nominal orientation (perpendicular to that of the polarizer) by an amount approximately proportional to the local brightness signal in the image in the LCTV. A volume phase grating near the LCTV disperses the light in this polarization image into red, green, and blue wavelengths. A projection lens forms a real image of the output plane of the LCTV on a projection screen.

An analyzer polarized perpendicularly to the nominal (zero-modulation) polarization is placed on the back focal plane of the lens, where it intercepts the blue component of the dispersed image spectrum. The light emerging from this analyzer has an intensity proportional to $\sin^2(\Omega)$, where Ω is the angle of rotation in the LCTV. Thus, the intensity of the blue pseudocolor component of the affected portion of the image increases with increasing brightness modulation in the affected portion of the image.

Another analyzer, placed to intercept the green spectrum, is polarized perpendicularly to the nominal polarization of light that emerges from the LCTV at maximum brightness modulation. The light emerging from this analyzer has an intensity proportional to $\sin^2(\Omega_{max}-\Omega)$, where Ω_{max} is the rotation in the LCTV at maximum brightness modulation. Thus, the intensity of the green pseudocolor component decreases with increasing brightness modulation.



In the **Optical Pseudocolor-Encoding Apparatus** the brightness modulation in the image from the television camera is transformed into polarization modulation in the LCTV, and then into pseudocolor modulation in the image on the projection screen.

A third analyzer placed to intercept the red spectrum is polarized perpendicularly to the bisector between the two extreme polarization states $\Omega = 0$ and $\Omega = \Omega_{max}$. The intensity of the output of this analyzer is proportional to $\sin^2(\Omega - \frac{1}{2}\Omega_{max})$; that is, in the red pseudocolor component, the midpoint of the gray scale is transformed to darkness, and the intensity increases as the brightness modulation departs (whether by rising above or falling below) from the midpoint. The outputs of the analyzers are combined on the projection screen, yield-

This work was done by Tien-Hsin Chao and Hua-Kuang Liu of Caltech for **NASA's Jet Propulsion Laboratory.**

In accordance with Public Law 96-517, the contractor has elected to retain title to this invention. Inquiries concerning rights for its commercial use should be addressed to

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NASA Tech Brief
National Aeronautics and
Space Administration

Study of Adaptive-Array Signal Processing

Techniques for the suppression of interference are compared.

A report describes a study of adaptive signal-processing techniques for the suppression of mutual satellite interference in a mobile (on the ground)/satellite communication system. There are two types of mutual satellite interferences. One type occurs when an Earth station receives. It can receive the desired signal from the satellite in the main lobe of its antenna while receiving an interfering signal from another satellite in a side lobe. The other type of interference occurs when an Earth station transmits. The portion of the signal radiated by one of its side lobes can be received by a satellite not intended to receive it and retransmitted by that satellite as an interfering signal along with the signal from another Earth station that it is intended to retransmit.

The study was motivated by the need for an effective low-cost technique that can exploit the geometrical or temporal differences between the desired and interfering signals. Although, in principle, such a technique could be used either at the satellites or at the mobile units on Earth, the emphasis in this study is on the latter.

The report presents analyses and numerical simulations of the performances of two approaches to signal processing for the suppression of interference. One approach, known as "adaptive side lobe canceling," involves the use of a primary antenna and a reference antenna that has a different radiation pattern in a phased array in which the amplitude and phase of the reference radiation beam relative to those of the primary radiation beam are controllable. The direction of an interfering satellite can be estimated during reception and used to place a null in the overall radiation pattern in the direction of the interfering satellite during transmission.

The second approach, called "adaptive temporal processing," is potentially the approach of lowest cost because it operates only on the primary beam. Adaptive time-domain filtering techniques that exploit both amplitude and Doppler-frequency offsets between the desired and interfering signals have been developed. One such technique involves the use of a cross-coupled phase-lock loop, in which one of two phase-lock loops locks onto the desired signal, while the other locks onto the interfering signal. An alternative technique, called the constant-modulus algorithm, senses and removes the incidental amplitude modulation of the received signal by interfering signals.

The basic conclusion that emerges from the study is that, of the approaches considered, adaptive side lobe canceling provides the most effective means for the suppression of mutual satellite interference. Furthermore, by using digital technology and developing custom microcircuits, one can reduce the cost of augmenting the existing mobile/satellite communication system with adaptive interference-suppression capability.

This work was done by Edgar H. Satorius of Caltech and Lloyd Griffiths of USC for **NASA's Jet Propulsion Laboratory**. *"Final Report on Adaptive Array Signal Processing Study."*
NPO-17492/TN

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NASA Tech Brief
National Aeronautics and
Space Administration

Temperature Dependence of Single-Event Effects

In most cases examined, vulnerability to these effects increased or remain constant with temperature.

A report describes an experimental study of the effects of temperature on the vulnerability of integrated-circuit memories and other electronic logic devices to single-event effects — spurious bit flips or latch-up in logic state caused by impacts of energetic ions. The study involved the analysis of data on 14 different device types. (Some types were nominally identical but made by different manufacturers.) The data were taken both from experiments performed by the authors for this purpose and from experiments performed previously by other authors.

In some instances, there are sufficient data to generate graphs. In others, only a narrative is possible because only two temperature data points are available. With the exception of one complementary metal oxide/semiconductor static random-access memory, the vulnerability of each device was found to increase or remain constant with increasing temperature, although to a different degree for each device. Further, with the exception of one instance in one of the previous studies, lowering the temperature was found to decrease the vulnerability. In this one instance, the temperature was lowered so far that the device lost its functionality.

This work was done by James R. Cross, Donald K. Nichols, Lawrence S. Smith, Mark A. Huebner, and George A. Soli of Caltech for **NASA's Jet Propulsion Laboratory**. *"Temperature Dependence of Single Event Phenomena."*
NPO-17870/TN

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NASA Tech Brief
National Aeronautics and Space Administration
NASA's Jet Propulsion Laboratory, Pasadena, California

Two-Way Optical Data Link on One Fiber

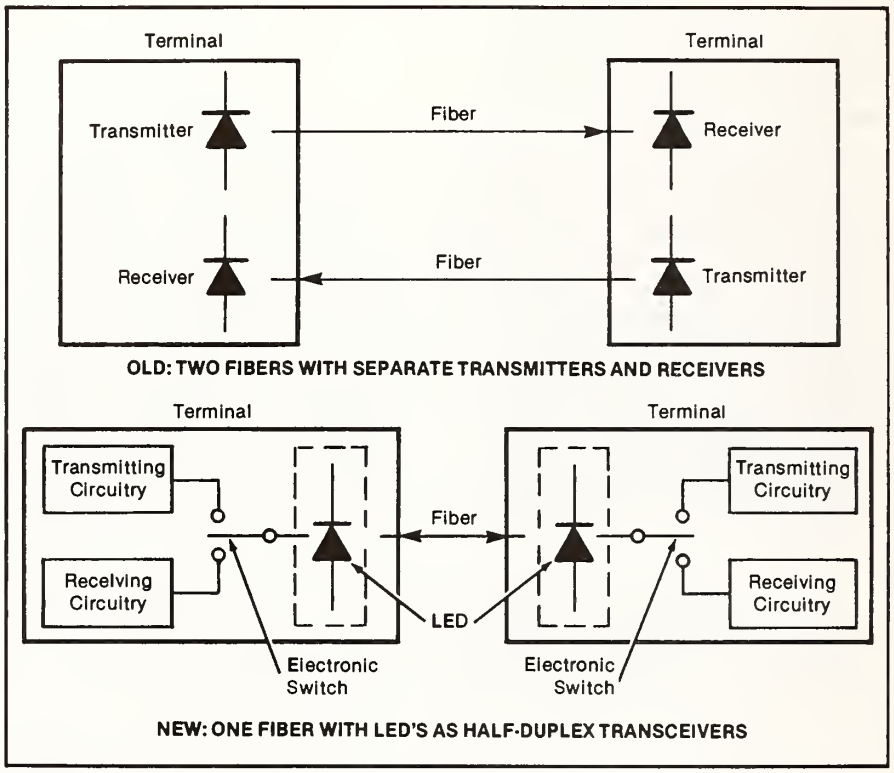
Dual-purpose LED's reduce cost.

An optoelectronic terminal for digital communication both transmits and receives over a single optical fiber. It uses the same semiconductor device — a light-emitting diode (LED) — as both the transmitting and receiving transducer.

A data link that consists of two such terminals communicating via an optical fiber is half-duplex; it does not carry messages in opposite directions simultaneously but rather in time-shared fashion: messages are alternately transmitted or received by each terminal, but transmitting and receiving modes of a terminal cannot operate simultaneously. Although the maximum possible data rate is only half that of a two-fiber, full-duplex link, the cost of the single-fiber link could be much lower.

Ordinarily, PIN photodiodes are used as receivers, and semiconductor lasers or LED's are used as transmitters in optical-fiber links. The possibility of using a LED as a receiver is mentioned in at least one introductory electronics text and was found to be practical. Reasonably high data rates are possible if the proper type of LED is selected, and optical-to-electrical conversin efficiency — ordinarily quite low for LED's — can be made acceptably high with the help of suitable electronic circuitry.

The use of a LED as a transmitter and receiver saves the cost of a separate receiving element at each end of the link. It also avoids the considerable cost and an unavoidable optical loss of 6 dB of an optical power splitter at each end to separate the transmitted and received beams of light. Each terminal includes a solid-state switch that switches the LED between the transmitting and receiving modes (see figure).



A **Single Module** alternately transmits and receives along a single two-way optical fiber. A switch alternately connects the light-emitting diode to transmitting and receiving circuitry. In contrast, a standard two-fiber, two-way link uses separate devices for receiving and transmitting.

A laser can also be used as a transmitter/receiver. However, lasers cost much more than LED's do, and are useful in high performance links where a combination of high data rate (≳5Mbit/s) and distance (≳1km) are needed.

This work was done by Harold Kirkham, Alan R. Johnston, Shannon P. Jackson, and Heather A. Friend of Caltech for **NASA's Jet Propulsion Laboratory.**
NPO-17884/TN

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Technology Application

Sandia National Laboratory

New Compact VISAR Interferometer Simplifies Operation

A more compact VISAR interferometer system for measuring shock-related motion such as that produced during an explosion has been developed by Sandia National Laboratories. The new design is less complex and easier to operate than earlier systems.

The VISAR (Velocity Interferometer System for Any Reflector) was invented about 20 years ago at Sandia and has become the standard for measurement of high-pressure shock wave phenomena in solids. It measures velocities ranging from tens to thousands of meters per second by using a modified unequal-leg Michelson interferometer.

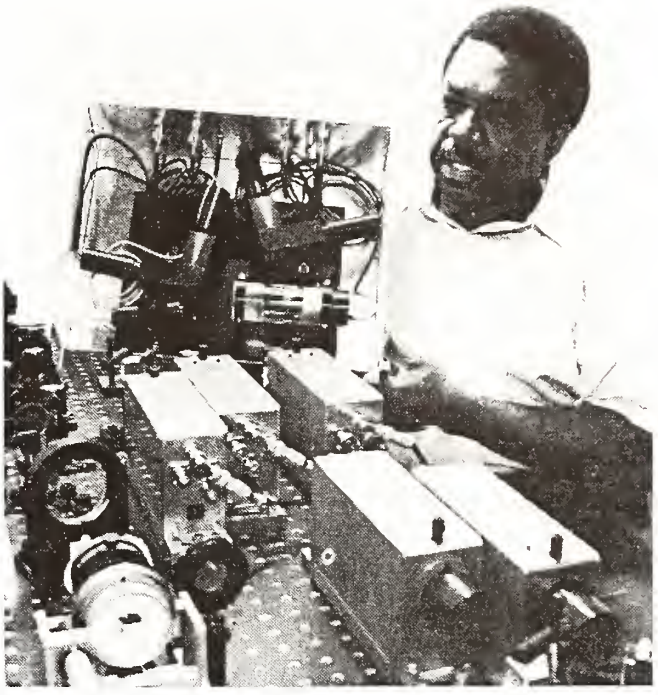
Sandia uses VISARs to measure velocities by determining the Doppler shift of laser light reflected from fast-moving surfaces, usually driven by explosives, pyrotechnics, or high-speed impacts. The Doppler shift is a change in wavelength caused by motion of the radiation source, the radiation receiver, or an intermediate reflector (in this case the target). Common examples of this effect are the variances in the pitch of the sound of a locomotive as it moves away from or toward an observer or of a burglar alarm as one moves toward or away from it.

The VISAR works by detecting wave interference—the effect created by the combination of two waves. If the beams from two coherent (i.e. laser) light waves come together in phase—that is, with their troughs and peaks in the same place at the same time—the only noticeable effect when they merge will be an intensified light (constructive interference). But if the waves are out of phase, they cancel each other (destructive interference). In a VISAR, as the reflector velocity changes, the interference phase changes, creating alternate cycles ofdark and light. By detecting these cycles, an interferometer can very precisely determine the Doppler frequency variations with time. A small computer is used to convert the data obtained to a velocity record.

Until now, Sandia's VISARs have been of a "breadboard" design—a table with the numerous optical components mounted on it. This arrangement allows the VISAR to be reconfigured to measure a wide range of velocities and accelerations. However, this flexibility also can be a disadvantage since the components require frequent precision adjustment to maintain alignment.

Compacted into single unit

Sandia engineers set out to design a VISAR that would not require these frequent readjustments and therefore be easier to use and less expensive. They accomplished this by designing a VISAR that had all of its key parts compactly incorporated into a single unit occupying about 1 cubic foot of space. A comparable breadboard VISAR takes up about 12 cubic feet.



New-generation VISAR shown here by co-developer O. B. Crump, Jr., is more compact, easier to operate than original breadboard version in foreground.

This "fixed-cavity" VISAR is prealigned at time of assembly and does not need further adjustments. Because this less complex system does not require operation by an optics technician, it is anticipated that it would be attractive to university and industrial laboratories doing basic science studies on material shock properties. Its simplicity of operation makes it suitable for operation by graduate students or industry technicians doing product testing.

In addition to the reduced operator setup and data processing time, the fixed-cavity system also offers the advantage of improved data quality achieved through elimination of numerous elements and shortening of optical path lengths.

In the fixed-cavity system, the light beams are routed from the laser to the test target surface and back to the interferometer through optical fibers. This allows the interferometer and its sensitive photodetectors, amplifiers, recording equipment, and the laser to be located far enough away from the test target and any large electrical noise sources to prevent electrical interference in the data. Sandia researchers currently are operating the device 100 feet from the test target with good resolution. In addition to eliminating many of the alignment problems associated with VISAR testing, the fiber optic arrangement reduces eye hazard by confining the high-power laser beams.

The only other optical path requiring alignment can be simplified by using a television alignment system incorporated into a detector head assembly to provide a magnified view of the target area.

The fixed-cavity VISAR was developed at Sandia by Philip L. Stanton, William C. Sweat, and O. B. Crump Jr. They have filed a patent disclosure with the Department of Energy. Several fixed-cavity VISAR systems have been assembled at Sandia and are being evaluated at DOE installations. □

FOR ADDITIONAL INFORMATION

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Brookhaven National Laboratory

Tracers Used to Locate Cable Leaks

Under the streets of New York City and the nation's other urban centers run thousands of miles of high-voltage electrical cables, carrying power throughout the cities.

The pipe-type cables, enclosed in steel pipes, are filled with a dielectric fluid medium to cool and insulate them.

Many of these cables are decades old. Utility company experts can tell when a line develops a leak by sensors that measure the volume and pressure of the dielectric fluid at the end of each cable line.

The question is, Along the 1- to 20- mile length of the typical cable buried three to five feet below street level, *where* is the leak?

In New York City, Consolidated Edison Company of New York has expended considerable effort and money to answer this question - to find the leaks quickly and without de-energizing the cable. But now, scientists at the Brookhaven National Laboratory's (BNL's) Tracer Technology Center, headed by chemical engineer Russell Dietz, have developed a faster and possibly less expensive method that could translate into savings for utility companies across the country. The BNL team is developing a process to tag the dielectric fluid with a small amount of liquid perfluorocarbon tracer (PFT), a carbon compound saturated with fluorine. When a leak occurs, the harmless PFT vapor rises to the street surface, acting as an invisible chemical flag marking the presence of a leak. PFTs can be detected in minute quantities by analyzers also developed at BNL.

Dietz says several useful applications of PFT tracers have been developed at the center since its inception in 1985. Perfluorocarbons are the chemical tracer of choice, he says, because "these compounds have a very low background in the atmosphere, so less of the material needs to be released to be detected."

And, he says, PFTs "are extremely stable, nonreactive in the environment, harmless to man, and don't affect the ozone layer."

In July of this year, Dietz and four associates ran their first major test of this technique with a five-gallon underground spill released for this purpose by Con Edison. Accompanied by a Con Edison protection vehicle, the BNL team drove in a van along the designated 30-block area - about 1.8 miles - using a device called a dual trap analyzer (DTA) to detect PFT vapors.

DTA is a twin sampling unit; one trap absorbs and concentrates a 12-liter air sample every six minutes; while that sample is being read by a gas chromatograph, the second trap is operating to take an equivalent sample. Dietz says the DTA can register atmospheric PFT levels of less than 50 parts per quadrillion (50 per 10^{15}).

With the DTA, the crew covered the 1.8 miles in 20 minutes. After additional passes in the van narrowed the location down to one or two blocks, one person went on foot with a portable, but less sensitive device that produces readings in 10-15 seconds to "sniff" the ground for what Dietz calls "hot spots."

With this technique, the crew located the only PFT hot spot; a crack in the street's center island within the 80-foot area determined by the DTA. Con Edison crews bored small holes in the pavement for a few feet apart, and the portable analyzer was used again to test the emerging vapors. Soon, they had pinpointed the location of the leak to within a foot.

"We were quite elated that within a 24-hour period a crew of five had found this leak to within plus or minus one foot," says Dietz. "There were no unforeseen problems - everything went extremely smoothly." Looking forward, Dietz says that with tracer technology, a utility company will not have to deenergize a leaking high-voltage line to locate the leak.

The Tracer Technology Center will be working with industry to transfer the technology for manufacturing reliable, easy-to-use PFT detectors. Dietz says he hopes to see utility companies using PFT tracers by 1992.

FOR ADDITIONAL INFORMATION: More information on this technology can be obtained from Bill Marcuse, (516)282-2103.

NIST Technology Update

National Institute of Standards & Technology
U.S. Department of Commerce, Gaithersburg, MD 20899

Infrared Wavelength Measuring Device Developed

A precision wavelength measuring device (lambdameter) for infrared radiation from diode and gas lasers has been developed at NIST. Intended as a working standard for wavelength measurement at 1.3 and 1.5 micrometers, the system also can be used in the red and near-infrared regions of the spectrum. The uncertainty of the lambdameter is about 2 parts in 10 million.

FOR ADDITIONAL INFORMATION: Details of construction and testing are contained in *Wavelength Measurement System for Optical Fiber Communications* (NIST TN 1336), which is available from NTIS, Springfield, VA 22161; (703)487-4600.

NTIS order number: PBPO-221805NAC
Price code: A03

NIST Technology Update

National Institute of Standards & Technology
U.S. Department of Commerce, Gaithersburg, MD 20899

Novel Device Measures a Variety of Electrical Pulses

A new measurement device that could help curb future electrical power outages as well as aid in the understanding of pulse phenomena such as heartbeats and pulsating fluids has been developed at NIST. The device, which makes real-time measurements of statistical correlations among pulses, is an improvement over other instruments that provide only limited information about pulse properties. NIST researchers have tested the instrument, called the stochastic analyzer for pulsating phenomena (SAPP), extensively by measuring the kinds of pulses that can occur when insulating materials in electrical systems are subject to stress. These "partial discharge" pulses can induce material degradation that leads to eventual failure of the insulation, causing electrical breakdown in the system. Gauging and understanding these pulses is important because faulty insulating materials could mean the loss of electricity in large geographic areas. The NIST device can be used to study the underlying physics of pulsating discharges and provide an indication of insulation performance. While they have mainly applied the device to electrical systems, NIST researchers say the SAPP can be used to investigate all kinds of pulsating phenomena.

NASA Tech Brief
National Aeronautics and Space Administration
NASA's Jet Propulsion Laboratory, Pasadena, California

Viewing Integrated-Circuit Interconnections by SEM

Back-scattering of energetic electrons reveals hidden metal layers.

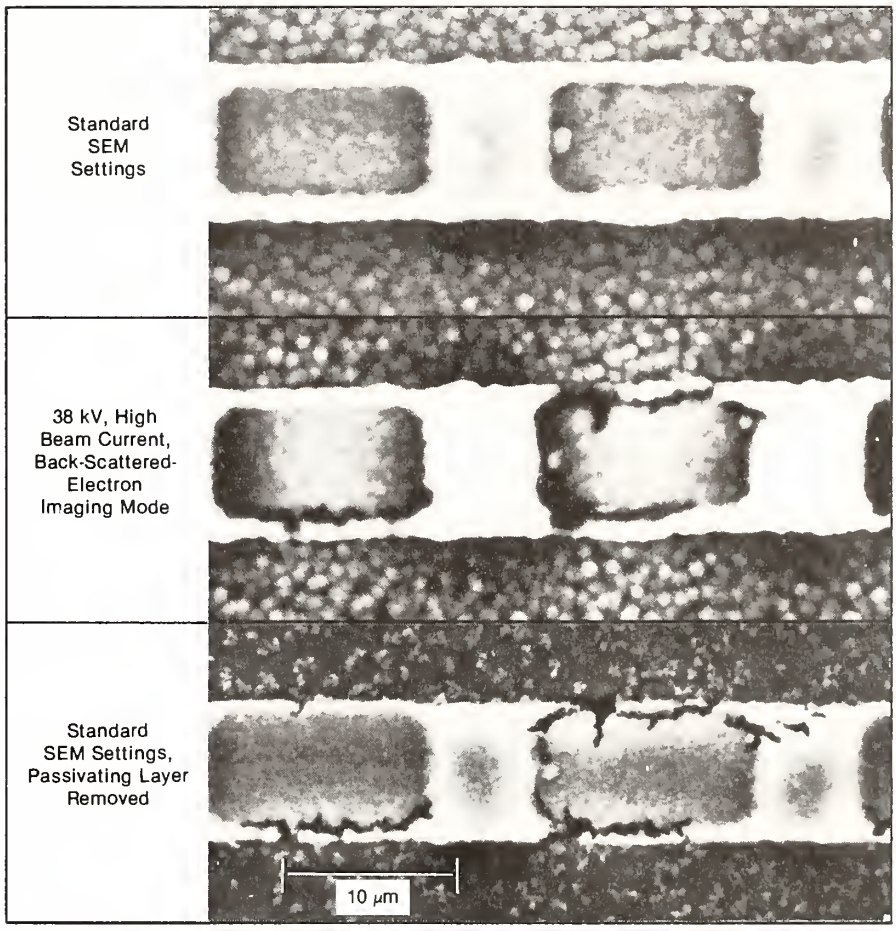
An experiment has shown that with suitable operating adjustments, scanning electron microscopy (SEM) can be used to look for defects in aluminum interconnections in an integrated circuit. Unlike in previous uses of SEM for this purpose, it is no longer necessary to etch away the passivating surface layer of silicon dioxide that covers the aluminum. One advantage of the modified SEM technique is that it enables the monitoring, in situ, of changes in the defects caused by changes in temperature. Another advantage is that it gives a truer picture of the defects, inasmuch as etching can change the stress field of the metal-and-passivation pattern, causing changes in the defects.

In the modified SEM technique, the electrons are accelerated to unusually high kinetic energy (accelerating potential > 35 kV), a high electron-beam current is used, and the instrument is operated in the back-scattered-electron imaging mode. Under these conditions, the metal, defects, and voids can be viewed directly through the passivating layer.

The upper part of the figure is a secondary electron micrograph, taken with standard SEM techniques and settings, with the passivating layer in place. This image shows a strip of aluminum with contact windows indicated by darker areas, but no defects or voids are visible.

The middle part of the figure is a back scattered electron image obtained with an accelerating potential of 38 kV and a high beam current, again with the passivating layer in place. This image also shows the aluminum through the passivating layer; in this case, however, voids in the aluminum are clearly visible.

The lower part of the figure is a micrograph taken to verify the middle part. The passivating layer was etched away with hydrogen fluoride, and a layer of AuPd 50 Å thick was sputtered onto the specimen to enhance contrast. The image was formed at standard SEM settings. The appearance of the voids is similar to that of the middle part of the figure; this suggests that the voids were there before and were not generated by the etch.


Standard SEM Settings
38 kV, High Beam Current, Back-Scattered-Electron Imaging Mode
Standard SEM Settings, Passivating Layer Removed
10 μm

These **Scanning Electron Micrographs** show that with appropriate operating conditions, defects and voids in metal interconnections of integrated circuits can be viewed directly through surface layers of silicon dioxide.

This work was done by Russel A. Lawton, Robert E. Gauldin, and Ronald P. Ruiz of Caltech for **NASA's Jet Propulsion Laboratory.**
NPO-17635/TN

FOR ADDITIONAL INFORMATION: *Contact: Director, Technology Transfer Division, P.O. Box 8757, BWI Airport, MD 21240; (301) 621-0100 Ext. 241*
REFER TO THE NUMBER LISTED AT THE END OF THIS ARTICLE

Energy

0145 Inexpensive Illumination Improvement—New thermal bridge increases fluroescent fixture efficiency and performace by as much as 20%. (Licensing Opportunity)

0146 Solar Furnace Melts World Record—Unique process conditions open a new world of industrial applications.

0147 Photovoltaics for Today's Utilities—Utilities are now finding cost-effective applications for photovoltaics technology.

0148 SERI Solar Cell Sets New Efficiency Record

0149 Antireduction Insulator for Solid-Electrolyte Cell—The depletion of oxygen from the electrolyte would be prevented. (Licensing Opportunity)

Software

0150 HPEAK: A Cool Tool for Analyzing Heat Pumps

0151 NIST Turns the HEAT on Hospital Energy Costs

Other Items of Interest

0143 Novel Device Measures a Variety of Electrical Pulses

Department of Energy

Technology Application

Lawrence Berkeley Laboratory

Inexpensive Illumination Improvement

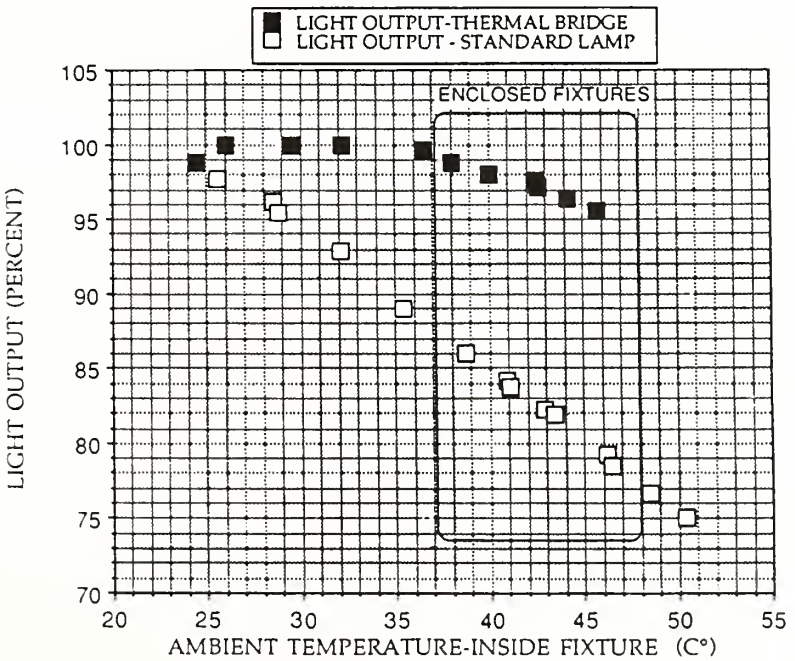
New thermal bridge increases fluroescent fixture efficiency and performace by as much as 20%.

Most fixtures sold in the United States today are only 60-70% efficient; excessively high lamp temperatures cause 15-20% of the efficiency loss.

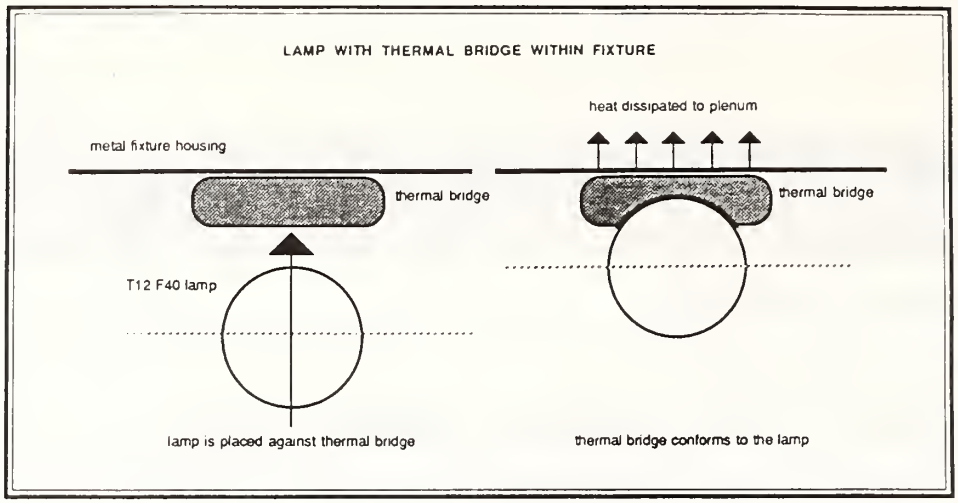
Investigators from Lawrence Berkeley Laboratory's Lighting Systems Research Group have developed a low cost system for spot cooling fluorescent lamps inside fixtures that will maximize efficiency, increase light output by 15-20%, and save energy.

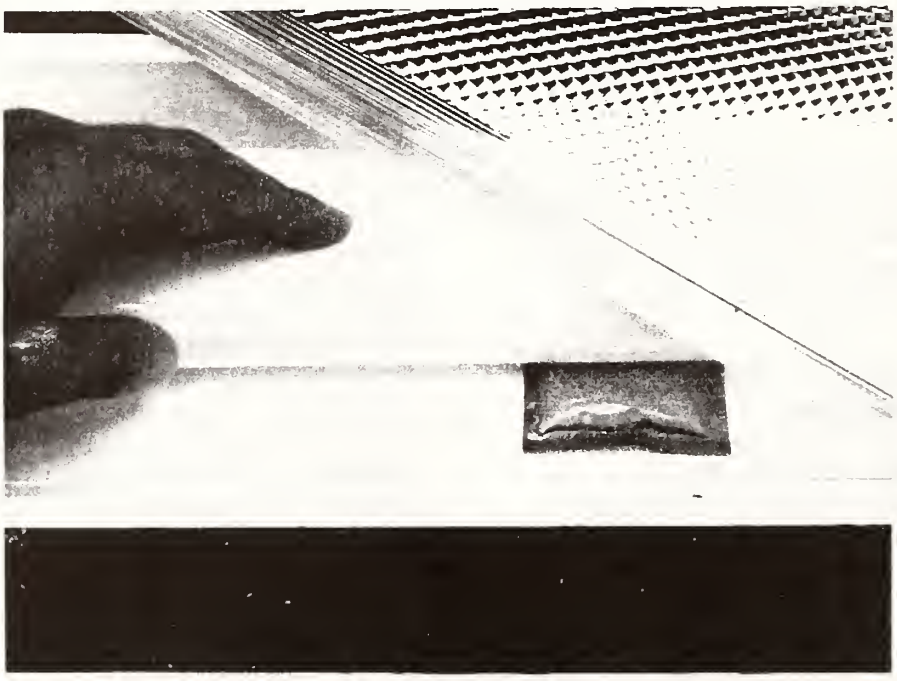
A fluorescent lamp is highly sensitive to changes in minimum lamp wall temperature. As temperatures rise beyond an optimal level of 25 degrees C (77 degrees F) for standard lamps, light output decreases. The constricted thermal environment in enclosed fixtures drives lamp temperatures to an undesirable 55-60 degrees C (130-140 degrees F). As a result, light output decreases by as much as 20% and system efficiency declines.

LBL's new Thermal Bridge greatly reduces this problem. Made up of a thermally conductive liquid enclosed within a thin flexible membrane, the system forms a small conformable thermal bridge between the tip of the lamp and the shell of the fixture. When a lamp is pressed against the bridge which tightly molds to the curved surface of the lamp, a close thermal contact is produced. The liquid convects heat away from a small area of the lamp to the walls of the fixture, where it is dissipated to the ambient or plenum volume surrounding the fixture, reducing the normally elevated temperature. Light output is maintained at or near optimum for a range of ambient temperatures 24-40 degrees C (77-104 degrees F) (See graph).



A plot of the variation in light output for a lamp operating with and without the thermal bridge system over the range of ambient temperatures surrounding the lamp. This experiment was conducted using a Philips lamp, Universal ballast, and thermal bridge system configured with 3M liquid heat sink material.


LAMP WITH THERMAL BRIDGE WITHIN FIXTURE
heat dissipated to plenum
metal fixture housing
thermal bridge
thermal bridge
T12 F40 lamp
lamp is placed against thermal bridge
thermal bridge conforms to the lamp



Market evaluation: Potential markets include light fixture manufacturers (20 million fluorescent fixtures produced each year could potentially use the thermal bridge), current users of fluorescent lights, building owners, and building construction industry. Development status involves one year of research and development to manufacture prototype, two full-time technicians, and low initial investment cost. Patent status: Patent pending.

Benefits include increasing fixture efficiency by 15-20%, the system being easy to fit and install, the system's not affecting routine fixture maintenance or bulb replacement, no specialized apparatus to cause a significant increase in fixture cost, no added hardware or manufacturing steps for fixture, and no dirt depreciation to fixture or bulb from mechanical or natural venting.

Technology highlights include the system's being easily incorporated into fixture manufacturing process, the system's bridge being small and unobtrusive (approximately one square inch in area), the system's being able to be used with single or multi lamp fixtures, fewer fixtures needed to produce the same amount of light (lowers building costs - fewer lighting connections - and it reduces electric bills), and retrofitting to existing fixtures.

FOR ADDITIONAL INFORMATION: Mark Owens, Technology Transfer Office, Lawrence Berkeley Laboratory, Building 90-1070, Berkeley, CA 94720; (415)486-6463.

Solar Energy Research Institute

Solar Furnace Melts World Record

Unique process conditions open a new world of industrial applications.

SERI has set a new world record for concentrated solar energy in air—a beam with more than 21,000 times the intensity of normal sunlight focused onto a small target area. The previous record, set by the Jet Propulsion Laboratory of Pasadena, Calif., was about 16,000 suns.

"This outstanding achievement opens up new avenues for solar research," said project leader Meir Carasso. "Essentially, we are redefining our use of the solar resource by creating new process conditions. We are limited only by our ability to contain this extremely concentrated form of energy."

Process conditions include very high temperatures, heating rates, and flux densities as well as controlled surroundings, allowing researchers to explore new industrial applications of solar energy.

The tracking heliostat of SERI's new solar furnace.

Focusing on Design

The solar furnace achieves its record-breaking intensities with a unique off-axis design developed by SERI engineers and based on research by the University of Chicago. In this configuration, a tracking heliostat reflects sunlight onto a faceted primary concentrator with a relatively long focal length. The primary concentrator focuses light onto a reflective secondary concentrator. The resulting off-axis light beam is directed into an enclosed test room. With this design, researchers can use a variety of receiver/reactors and carefully control process conditions.

The primary concentrator alone exceeded design expectations by reaching concentrations of 2500 suns. With the compound parabolic secondary concentrator in place, concentrations on the target area averaged about 21,000 suns. Peak concentrations may have exceeded 25,000 suns.

Harnessing the Sun's Energy

SERI's solar furnace opens up a new world of possibilities for photochemistry and materials processing.

A highly reflective aluminum coating on the heliostat and primary concentrator helps retain

high-energy photons in the ultraviolet portion of the solar spectrum. These photons are necessary for advanced photochemical reactions such as detoxifying hazardous waste, a process that could replace or supplement conventional disposal methods requiring considerable amounts of utility-generated power.

Rapid heating rates—up to 1 million degrees per second—promise to increase yields of chemicals, fuels, and other products when the reaction conditions are favorable. Other possible applications of the solar furnace include transformation and hardening of metal surfaces into space-age alloys that resist corrosion, friction, and oxidation.

The solar furnace also allows researchers to grow semicrystalline structures. Preliminary experiments involving deposition of thin films with special properties—for example, high-temperature superconductivity—have been very promising.

Researchers plan to develop these and other applications of the solar furnace during the next five to seven years. Plans also include modifying the secondary concentrator to produce intensities of more than 50,000 suns. ♦

For Additional Information:

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(303) 231-7303

Refer to Volume XII, Number 3/TN

Solar Energy Research Institute

Photovoltaics for Today's Utilities

Utilities are now finding cost-effective applications for photovoltaics technology.

Photovoltaic (PV) cells have long been cost-competitive for many small-scale applications. First used to power satellites in the 1960s, PV systems rapidly came into use for remote military equipment and consumer products. Now that PV cell costs have dropped 95%, and module costs continue to decrease by 50% or more every five years, PV is starting to make its first significant penetration of the utility market.

California's Pacific Gas & Electric Co. (PG&E) reports that 420 utility-owned PV systems were operating in its service area at the end of 1989, and predicts that 720 may be in place by the end of this year. Economic analyses revealed that these stand-alone systems are more cost-effective than traditional power supply options, even without subsidies. The systems are distributed both near to and distant from the grid, throughout and beyond the utility's service area.

Systems owned by PG&E fill a wide variety of power needs, including remote residences, gas-flow computers, water-level sensors, cathodic protection systems, gas meters and samples, meteorological stations, aircraft warning beacons, security lighting, microwave repeaters, automatic gate openers, and remote sectionalizing switches. At the end of 1989, about 85% of PG&E's systems were being used to power gas flow computers, water level sensors, and automated gas meters; planned 1990 installations also emphasize these three applications. However, these applications accounted for only 27% of the utility's PV capacity at the end of 1989. The application using the most PV capacity was cathodic protection.

Photovoltaic modules provide cost-effective cathodic protection for California's Pacific Gas & Electric Co. (Photo courtesy of Christina Jennings/PG&E)

PV Beats Line Extensions In PG&E Study

A recent PG&E study compared capital and life-cycle costs incurred by a typical remote residential customer for a privately-owned PV system, a utility-owned PV system, a diesel generator, and three different lengths of conventional power-line extensions. Results showed that the PV systems are the least expensive option for customers located more than ¼ mile from an existing power line. (Diesel power had the lowest front-end cost, but its life-cycle cost was higher than that of either PV system.)

Rising capital and O&M costs for traditional supply options, such as

power line extensions, are making PV systems more economically attractive to utilities. O&M costs for line extensions include tree trimming, replacement of lines and transformers after violent storms or lightning strikes, and replacement of poles rotted by moisture. PG&E estimates that it trims about 3.7 million trees each year at a cost of about $25-$30 a tree, and the utility industry as a whole spends more than $500 million a year on this routine activity. Utility poles cost $1000-$4000 to replace.

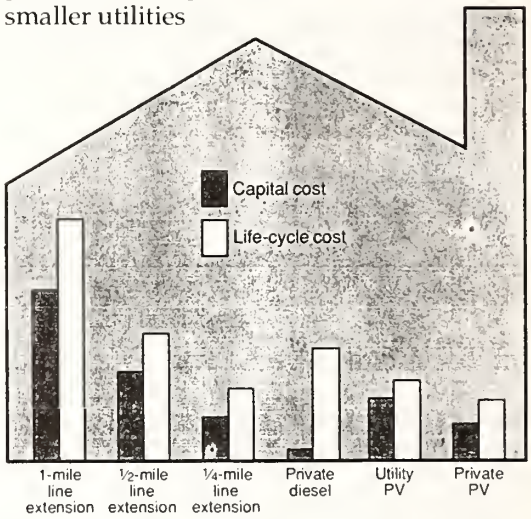
In contrast, the simplicity of PV systems—which convert sunlight to electricity with no moving parts—results in very low O&M costs and high reliability. The utility's cost-related risks are up front where they are easier to calculate and minimize; long-range risks, such as those associated with escalating fuel costs, are virtually eliminated. PV systems are modular and can be purchased in small power-producing increments for optimum load matching. And when compared to more traditional alternatives, PV systems have short construction lead times, high mobility, and minimal environmental impact.

The size of an economical PV system depends on its distance from the existing power line. A 1.2-kilowatt PV system becomes economical at about ¼ mile. A four-kilowatt system becomes cost effective at distances of one mile or more—a common situation in the Great Plains and the West. While the capital costs of today's PV systems are sometimes higher than other options, the overall life-cycle costs are often much lower.

SERI Plans Cooperative Utility Projects

Other utilities besides PG&E are becoming interested in the cost-effective applications of PV. For example, Southern Company (a large Southeast utility) estimates that it has several thousand possible applications.

SERI is now cooperating with Sandia National Laboratories and the Electric Power Research Institute to help utility engineers recognize the many applications of PV systems and to install small prototypes. The size of these PV systems will make them affordable by most utilities, but seed money is often provided to help smaller utilities with their purchases. To be eligible for funding, the installation must be cost-effective for its specific application. At least one utility project is planned for FY 1990, with more to follow during the next few years.



PG&E's cost study showed that stand-alone PV systems can be more economical than conventional line extensions.

More information on the current and future applications of PV technology can be found in "Photovoltaics—Today's Reality, Tomorrow's Promise," an article by SERI's John Thornton, Ken Zweibel, and Richard DeBlasio in Energy Engineering, *Vol. 87, No. 3.*

For Additional Information:

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Refer to Volume XII, Number 3/TN

Solar Energy Research Institute

SERI Solar Cell Sets New Efficiency Record

SERI researchers have just measured efficiencies of 31.8% for a new type of concentrator solar cell. These are the highest efficiencies ever obtained for a SERI-developed cell of any type.

The record-breaking monolithic tandem cell consists of layered indium phosphide (InP) and indium gallium arsenide (InGaAs). These materials respond to different portions of the solar spectrum and thereby capture more of the sun's energy than typical cells. Efficiencies increase under concentrated sunlight (up to 100 suns), making the cells suitable for use in tracking collectors. They are also ideal for space applications because indium-based materials resist the degrading effects of radiation outside Earth's protective atmosphere.

At light intensities of 50 suns, test cell efficiency was 31.8% under terrestrial conditions. In space, the efficiency would be 28.9%, also a new record for a monolithic tandem cell. Comparable efficiencies were observed for several cells from the same batch.

Higher efficiencies are expected for this cell technology. Researchers are now optimizing cell design for maximum performance.

Research and development of the InP/InGaAs cell was partially supported by the Naval Research Laboratories.

For Additional Information:

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Refer to Volume XII, Number 3/TN

NASA Tech Brief
National Aeronautics and Space Administration
NASA's Jet Propulsion Laboratory, Pasadena, California

Licensing Opportunity

Antireduction Insulator for Solid-Electrolyte Cell

The depletion of oxygen from the electrolyte would be prevented.

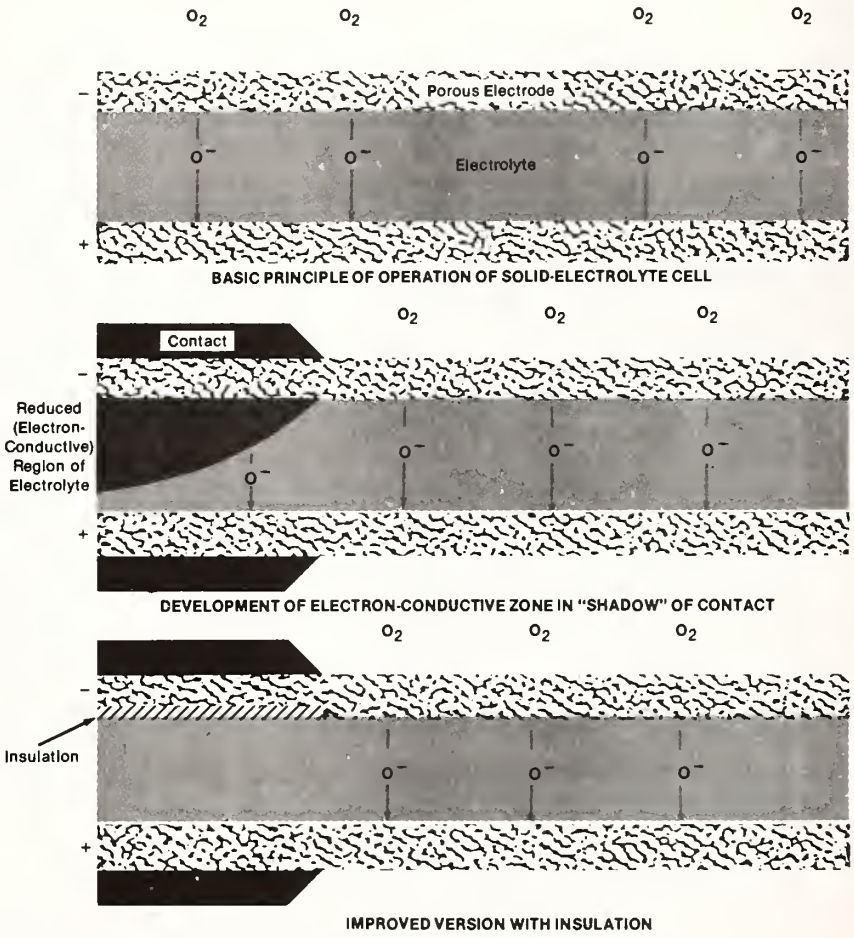
It has been proposed to add a layer of electrical insulation between the solid electrolyte and the portion of the porous negative electrode under the negative metal contact in a solid-electrolyte cell. The insulation would help to maintain the efficiency of the cell by preventing the "shadow" effect that degrades the portion of the electrolyte under the negative contact and sometimes near seals.

A typical solid-state electrolytic cell (see top of figure) includes a solid electrolyte (e.g., ZrO_2) sandwiched between porous metal electrodes (e.g., Pt sponge). The electrodes are permeable by gas, and the electrolyte is permeable by O^- ions but not by O_2 molecules. When a voltage is applied across the cell, O^- ions are formed at the negative electrode, then migrate across the electrolyte to the positive electrode where they are neutralized back into O_2. Thus, the cell acts as a pump for oxygen. Such a cell could also be used as an oxygen-pressure sensor or as a fuel cell to generate electricity.

For maximum efficiency, all of the electrical conduction of the cell should be in the transport of ions. To the degree to which the electrolyte exhibits electronic or hole conduction, the cell loses efficiency through increased resistive heating and partial or total diversion of the current through the nonionic short circuit. This can occur where, for example, the ZrO_2 electrolyte is reduced to ZrO_{2-x}, which is a strong conductor of electrons.

In a region of the cell under the negative electrode where the electrolyte is "shadowed" by a contact, seal, or other material impermeable by gas, O^- ions can still migrate from and through the electrolyte to the positive electrode, but O_2 gas cannot diffuse readily into the electrolyte to replenish the O^- ions lost from the electrolyte. Thus, the affected portion of the electrolyte is partly reduced to ZrO_{2-x}, becoming a conductor of electrons (see middle of figure). If the region of depletion grows until it touches the positive electrode, it short-circuits the electrolyte, drastically reducing the flow of oxygen.

In the proposed version of the cell (see bottom of figure), the insulation would suppress electrical current in the contact "shadow," so that ions would not migrate out of the shadow. Even if the electrolyte in the shadow were to become a conductor of electrons by reaction with the contact metal or by some other process, the insulation would also block the resulting electronic conduction. In making the proposed cell, the layer of insulation would be deposited by masked evaporation, sputtering, or another well-known technique. The insulation could be alumina, silica, or a refractory insulating ceramic.



The **Solid-Electrolyte Cell** is depicted in aspects of its design and operation.

This work was done by Paul J. Shlichta of Caltech for **NASA's Jet Propulsion Laboratory.**

Inquiries concerning rights for the commercial use of this invention should be addressed to the Patent Counsel, NASA Resident Office-JPL. Refer to NPO-17211/TN.

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NIST Technology Update

National Institute of Standards & Technology
U.S. Department of Commerce, Gaithersburg, MD 20899

Computer Software

HPEAK: A Cool Tool for Analyzing Heat Pumps

Heat pumps are getting smarter. Some of the newest models not only heat and cool your home but provide hot water as well. But how do these advanced systems affect energy consumption and are they cost effective? To get some answers, NIST researchers developed a computer program to evaluate the performance and economics of conventional and advanced heat pump and water heating systems. Called HPEAK (Heat Pump/Economic Analysis of Kilowatt-hours), the program can simulate the daily, hour-by-hour operation of a heat pump and can predict the monthly and annual energy consumption as well as peak demand times. It also can be used to analyze the cost effectiveness of operating a particular heat pump system and can compare the energy consumption and costs of conventional and advanced heat pump systems. Designed to run on a personal computer, HPEAK can be used by electric utilities, heat pump manufacturers, and building researchers.

FOR ADDITIONAL INFORMATION: The software and related documentation is available from the Electric Power Research Institute in Palo Alto, CA; 214/655-8883.

NIST Turns the HEAT on Hospital Energy Costs

NIST researchers have developed a personal computer (PC) program to help hospital managers evaluate the effectiveness of various energy conservation measures. HEAT - the Hospital Energy Analysis Toolkit - is a fully documented, menu-driven program. The user enters specific information about the facility - its location (zip code) and local energy prices, for example - and a description based on 21 prototype energy zones. Energy conservation plans of up to 10 elements can be specified for each zone. HEAT calculates and reports expected annual energy savings and economic results by zone for each plan, taking into account all interactions among different elements of the plan.

FOR ADDITIONAL INFORMATION: The program runs on a standard MS-DOS PC with a hard disk drive and is available for $60 plus $3 handling, prepaid, from the National Technical Information Service, Springfield, Va. 22161. Request PB90-504036NAC.

Engineering

0152 Directory Published on Weights & Measures Labs
0153 Improving Synchrotron Performance: Real-Time Harmonic Closed-Orbit Feedback System
0154 Oil Water Separation Made Easier by Using Nonpersistent Emulsifying Degreasers
0155 Computing Impingements of Rocket Exhausts—The user can choose among a variety of configurations, data, and theories.
0156 Control-Volume Analysis of Thrust-Augmenting Ejectors—A new method of analysis applies to transient flows.
0157 Dissipation of Energy in Extension of Cracks—Dissipation in an elastic-plastic material is calculated by a two-dimensional finite-element method
0158 Experiments on Active Members in large Space Structures—Built-in sensors and actuators monitor and control vibrations.
0159 Flexible Animation Computer Program—Vibrations, thermal distortions, and stresses are animated in color.
0160 Laser Velocimetry in Low-Speed Wind Tunnels—Airflow velocity is measured with minimal perturbation. (Licensing Opportunity)
0161 Offset joint for Segmented Pressure Vessel—A slight offset reduces joint gap under pressure. (Licensing Opportunity)
0162 Precise Hinge has low Friction—Blade-in-groove rotation allows free movement through a limited arc.
0163 Simulating a massive, Mobile Structure—The mass of the mobile structure can be varied.

Software

0164 Capillary Pumped Loop Modeler—This program simulates the thermodynamic performance of capillary pumped loops.
0165 New Software Monitors System Behavior, Detects Deviations and Diagnoses the Possible Cause

Testing & Instrumentation

0166 Vehicle to Clean and Inspect Mine Track
0167 Radial Profilometry—Inner surfaces of tubes and tubelike cavities are measured optoelectronically. (Licensing Opportunity)
0168 Schlieren System for Flow Studies in Round Glass Pipes—Cylindrical lenses compensate for refraction in the walls. (Licensing Opportunity)

Other Items of Interest

0183 Increasing the Dexterity of Redundant Robots—Redundant coordinates are used to define additional tasks. (Licensing Opportunity)
0190 Clothing Insultating Material Is More Efficient
0202 Advanced Field NDE System Producibilty, Advanced Real-Time Inspection System

NIST Technology Update

National Institute of Standards & Technology

U.S. Department of Commerce, Gaithersburg, MD 20899

Directory Published on Weights & Measures Labs

State Weights and Measures Laboratories: State Standards Program Description and Directory (NIST SP 791) is designed to help manufacturers and others in commerce and industry locate and obtain needed measurement services. The directory is a guide to state and other labs certified by NIST that are capable of performing reliable measurements with staff trained in proper procedures. To be certified in a particular area, each state must have a trained metrologist and an adequate facility, and must demonstrate on a continuing basis that it is capable of providing valid measurements. NIST certification indicates the laboratory is capable of providing a measurement service, but each state is responsible for verifying its measurement traceability. The directory contains the following information for each lab: the certification period, if certified by NIST; lab staff members, addresses, and telephone or fax numbers; services available; and fees, if any, for services.

FOR ADDITIONAL INFORMATION: A copy of the report is available from NTIS, Springfield, VA 22161; (703)487-4600.

NTIS order number: PB90-257650NAC

Price code: A04

Technology Application

Brookhaven National Laboratory

Improving Synchrotron Performance: Real-Time Harmonic Closed-Orbit Feedback System

Researchers at Brookhaven National Laboratory have developed a novel feedback system that improves the performance of synchrotron radiation facilities. Called the Real-Time Harmonic Closed-Orbit Feedback System, the system is located at Brookhaven's National Synchrotron Light Source, the world's most powerful source of x-rays and ultraviolet radiation.

At present, the system is installed at the facilities vacuum ultraviolet (VUV) ring, where its function is to stabilize the orbit of the circulating electron beam around that entire ring. Measured vertically, the size of the beam is about 100 microns, or the width of a human hair. Ordinarily, the beam can move up and down by as much as 200 microns. This movement, however, is undesirable because it leads to large-intensity fluctuations, which present serious difficulties for many of the VUV experimenters.

Brookhaven's feedback system stabilizes the orbit of the electron beam by reducing the movement to between 50 and 60 microns. The system is based upon a harmonic analysis of the orbit movements and the magnetic fields within the ring. (Magnets are used to keep the electrons in a circular orbit.) Four detectors located around the ring collect information on beam position, and, in real time, the position signals are transformed by the use of simple electronics into analog signals proportional to the main spatial harmonic components of the orbit distortion. The output signals are then used to correct the orbit motion over the hole ring. Because orbit motion occurs in all synchrotron light facilities, feedback systems are already widely used. These previous systems, however, only stabilize the beam at one point along its path–for example, at the location of a particular experiment. Brookhaven's harmonic feedback system is the first one that works both globally and in real time, with the orbit corrections done almost instantaneously.

Already, synchrotron light facilities exist at four sites in the U.S., with three new machines planned or under construction. Europe has four synchrotron light facilities, Japan has four, and new machines are planned at various locations all over the world. These facilities represent an investment of billiions of dollars. Brookhaven's innovative harmonic feedback system will allow scientists to take full advantage of the exciting research opportunities afforded by synchrotron light.

The Real-Time Harmonic Closed-Orbit Feedback System won a 1989 R&D 100 Award.

Literature: L.H. Yu et al., Real Time Harmonic Closed Orbit Correction, BNL Report No. 42581 (March 1989).

Patent Status: Not patented.

Applications/Spinoffs: Applicable to any snychrotron, particularly synchrotron radiation facilities because of their exacting orbit stability requirements.

FOR ADDITIONAL INFORMATION: William Marcuse, Office of Technology Utilization and Industry Sponsored Research, Building 902-C, Brookhaven National Laboratory, Upton, NY 11973; (516) 282-2103. Refer to BNL/AA-47.

NCEL
Techdata Sheet

NAVAL CIVIL ENGINEERING LABORATORY
PORT HUENEME, CALIFORNIA 93043

Oil Water Separation Made Easier by Using Nonpersistent Emulsifying Degreasers

In response to Federal regulatory pressures, the Chief of Naval Operations has directed Naval activities to reduce their hazardous waste generation by at least 50% by 1992. The bilge water and wastewater stream generated from various shipboard cleaning operations that accumulates in both bilges and ship tankage has been identified as one of the Navy's eight major wastestreams. These wastestreams are a particular problem because they contain significant amounts of persistent oil-water emulsions that have come from using the wrong kinds of cleaning degreasers.

Processing such wastestreams begins with oil-water separation, either aboard ship or shore. However, clear-cut separations seldom occur. Instead, large quantities of oily waste in vaguely defined intermediate stages result that cannot be subsequently treated as either water or oil.

The condemnation of the Navy's favorite receiver of bilge water from ships separators, the DONUT, is largely due to the emulsified oil problem. The shipboard oil-water separators being installed throughout the Fleet are also experiencing off-performance for the same reason. Even the large separator systems ashore do not work well because of the often unacceptable emulsified condition of bilge discharges.

Handling costs exceed $1 million per year since the emulsions accumulated from these separators cannot practically be sent to landfills or accepted by NPDES-permitted treatment plants. These emulsions must be stored and allowed to break over long periods of standing time, or they must be treated (with limited success) by thermal knockout or subjected to other forms of processing, none of which is cheap.

Products called "degreasers" usually contain large proportions of emulsifiers and solvents. General purpose cleaners, on the other hand, typically have less emulsifier, more detergent, and may contain no solvents at all. For shipboard cleaning operations, particularly those involving the cleaning of the bilge itself and other ship compartments and tanks, *a degreaser that does not form persistent emulsions, yet provides the needed effectiveness for removing oil and grease, is clearly needed.*

In response to this oily challenge, the Naval Civil Engineering Laboratory (NCEL) evaluated eight degreasers currently used within the Navy plus 28 that were effective in shipboard cleaning operations, while avoiding the bilge water-oil complication. The goal of the study was not only to find such materials, but to evaluate those already in use in the Navy to determine their suitability for continued application.

The preliminary performance criteria and test procedures used for laboratory testing were furnished by Norfolk Naval Shipyard. The criteria were later modified in order to qualify optimum materials with respect to both primary product function (cleaning capability) and the environmental implications in its use (wastewater separability).

The results of the study clearly showed that most of the degreasers in use in the Navy today that were tested can pose end of pipe treatment problems. Out of the 36 total degreasers accepted for the test program, only *two* passed all the criteria described in Table 2 and *one* passed all except the surface pH, which was 9.5 - a marginal situation. These three degreasers were considered the best overall for ship cleaning operations involving production of wastewater collected in ship bilges and tankage.

Ten of the 36 degreasers tested passed the most critical test - Persistence of Oil in the Wastewater Phase. In accordance with test protocol, all others were disqualified from further testing.

The materials that can be recommended at this time for shipboard degreaser-cleaning applications are SUNSHINE - NATROSOL, UNITOR - CLEANBREAK, CHEMSEARCH - DUOPOWER (pH slightly out of spec).

Studies are being proposed for the field evaluation of the above materials in actual shipboard working environments. Work will also be proposed for the evaluation of additional test materials so that a wider selection of qualified degreasers can be developed. Interest and cooperation from the manufacturers has been excellent, but hopefully will be intensified when the results of this work are published shortly and solicitation for new products can be placed in the Commerce Business Daily.

FOR ADDITIONAL INFORMATION: Jerry Dummer, Code L03C (Facilities Engineering Support Division); 805-982-1599; and Tom Torres, Code L71 (Environmental Protection Division); 805-982-1658.

NASA Tech Brief
National Aeronautics and
Space Administration

Computing Impingements of Rocket Exhausts

The user can choose among a variety of configurations, data, and theories.

SFPLIMP, the Source Flow Plume Impingement Program, computes the forces, moments, contamination, and heating rates caused by the impingement of plumes on orbiting spacecraft from jets firing at high altitudes. A mathematical model can be developed for any type of jet impinging on a wide range of configurations defined by the user.

Input data on jets include the number of jets, location and/or orientation, and the chemical composition of the plume (each species and its mole fraction). A table of chemical species containing heating-rate data, vapor-pressure data (where available), and evaporation-rate data (where available) is provided. Species not in the table can be used if heating rates are not required. Species for which vapor-pressure data do not exist are assumed to stick to surfaces, no matter what flow-field conditions exist. Evaporation-rate data for species not provided by SFPLIMP may be inserted by the user.

The target can be modeled mathematically by combining flat plates and three-dimensional shapes. Available subshapes include right triangles, rectangles, circles, circular cones, circular cylinders, spheres, and polynomials of revolution. Temperature can be calculated globally or for each component in the target.

Forces and moments on the spacecraft are computed for the continuum, transition, and free-molecular regions. Results from continuum regions have been enhanced through the incorporation of tables of data for orbiter primary and vernier reaction-control-system jets. The user has control over the impact theory used. Choices are Newtonian, modified Newtonian, or corrected modified Newtonian. Contamination levels are modeled mathematically through the determination of maximum deposition rates on each subshape of the configuration or the net deposition (including evaporation) on each subshape. Free-molecular heating rates are computed in the far-field region. Convective laminar and turbulent-boundary-layer heating rates in the continuum region are computed for each subshape. Samples include mathematical models of several space-station configurations and the Hubble Space Telescope.

SFPLIMP is written in FORTRAN 77 (99 percent) and VAX DCL screen-management utilities (1 percent, not essential) for use on a DEC VAX 11/780 computer running under VAX VMS 4.6. Version 3.2 was developed in 1988.

This program was written by M. Cerimele and B. Drake of Lockheed Engineering & Management Services Co. for **Johnson Space Center.**
MSC-21419/TN

FOR ADDITIONAL INFORMATION: *Contact: Director, Technology Transfer Division, P.O. Box 8757, BWI Airport, MD 21240; (301) 621-0100 Ext. 241*
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NASA Tech Brief
National Aeronautics and Space Administration
Lewis Research Center, Cleveland, Ohio

Control-Volume Analysis of Thrust-Augmenting Ejectors

A new method of analysis applies to transient flows.

A method of analysis of transient flow in a thrust-augmenting ejector is based on a control-volume formulation of the governing equations. Thrust-augmenting ejectors are being considered as potential elements of propulsion subsystems of short-takeoff/vertical-landing airplanes.

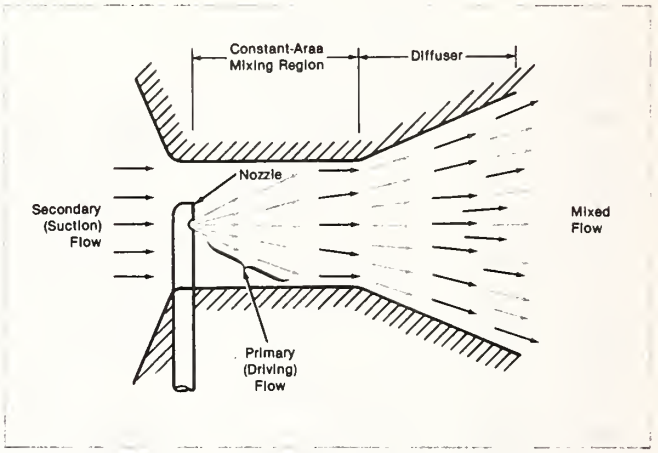
A thrust-augmenting ejector is often described as a fluidic pump that employs the momentum of a fast jet (the drive or primary flow) from a primary nozzle to entrain and pressurize a suction stream (the secondary flow). A typical thrust-augmenting ejector consists of a high-pressure nozzle to accelerate the primary flow, an inlet section to accelerate the secondary flow, an intermediate section in which the primary and secondary flows exchange momentum, and a diffuser to match the pressure of the discharge with that of the atmosphere (see figure).

The further exploration of ejector concepts imposes the following three requirements on the numerical simulation of the performance of an ejector:

1. The mathematical model must be predictive, not parametric.
2. The turbulent flow in the mixing region of the ejector must be appoximated.
3. The final system of equations must be amenable to simulation in real time.

The new method of analysis was developed to meet these requirements.

The control-volume formulation of the governing equations yields time derivatives of the field-variable volume integrals that express the conservation of energy, mass, momentum, and entropy. Because these volume integrals cannot be converted into surface integrals, the spatial distributions of the field variables must be approximated. Under the assumption that the physics of the mixing region dominate the characteristics of the performance of the ejector, the spatial subdivision of the mixing region enables the approximation of the conditions in each subvolume by characteristic profiles of velocity, pressure, and temperature.



In a **Thrust-Augmenting Ejector** a fast jet (the primary flow) entrains a slower secondary flow.

Extending downstream along the centerline from the inlet plane of the mixing region, there is a potential-core region characterized by fairly uniform axial velocity, with no radial velocity. Surrounding the potential core is the region of mixed flow where the centerline velocity decays with increasing radius, due to transport of momentum to the entrained secondary flow. The potential-core region is represented by an analytical model calibrated by experimental data. The turbulent flow is represented by self-similar profiles of turbulent-flow-field variables. Time derivatives of the volume integrals are reduced to time derivatives of the characteristics of the field variables. Then treating the surface integrals in the usual way, one obtains a set of differential equations in time.

Inasmuch as the focus is upon the calculation of thrust generated by the ejector, fewer than 10 subdivisions of the mixing region are needed. Although the resulting description of the flow in the mixing region is terse and the turbulent interaction between the primary and secondary flows is crude, the final equations have the potential to predict thrust in real time, meeting the requirements.

This work was done by Colin K. Drummond of Sverdrup Technology, Inc., for **Lewis Research Center.** *Further information may be found in NASA CR-182203 [N89-12566], Price Code: A08 "A Control-Volume Method for Analysis of Unsteady Thrust Augmenting Ejector Flows."*

Copies may be purchased from the National Technical Information Service, Springfield, Virginia 22161, Telephone No. (703) 487-4650. Rush orders may be placed for an extra fee by calling (800) 336-4700. *LEW-14877/TN*

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NASA Tech Brief
National Aeronautics and Space Administration
Langley Research Center, Hampton, Virginia

Dissipation of Energy in Extension of Cracks

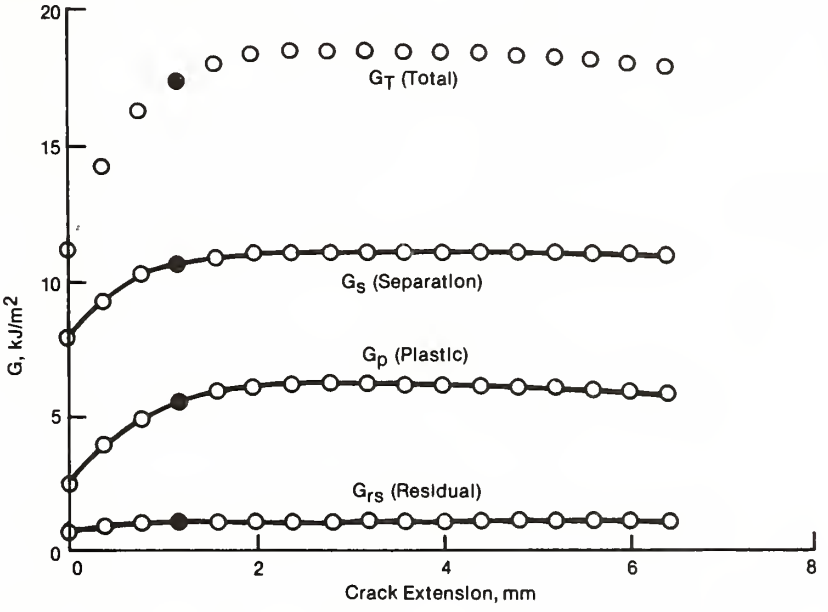
Dissipation in an elastic-plastic material is calculated by a two-dimensional finite-element method.

The extension of a crack in an elastic-plastic material involves the dissipation of energy through the creation of new crack surfaces and by yielding. An understanding of the energy-dissipation process in fracture may provide guidance for the development of tougher materials and could provide a basis for the prediction of the absorption of energy during failure. An analytical procedure has been developed to calculate the various components of the dissipation of energy during the extension of a crack and to relate them to the total dissipation of energy computed from the global load-displacement response.

A two-dimensional, elastic-plastic, finite-element analysis was used to implement the procedure. A standard compact specimen made of an elastic-plastic material was analyzed. The specimen was modeled mathematically by use of constant-strain triangular elements. Fracture was simulated analytically by use of the critical crack-tip-opening-displacement (CTOD) criterion. The crack was considered to be extended by release of the force at the tip of the crack in steps.

The analysis was repeated for three material toughnesses, which were simulated by using three different values for the critical CTOD. The magnitudes of the components of the dissipation of energy were compared with the total dissipation of energy for the different material toughnesses. The effect of critical CTOD on separation of the crack and on the rate of plastic dissipation of energy were also examined.

Results from the analyses showed that the total rate of dissipation of energy, G_T, consisted of three components: (1) the crack-separation-energy rate, G_s, (2) the plastic-energy-dissipation rate, G_p, and (3) the residual-strain-energy rate, G_{rs} (see figure). All three energy-dissipation components and the total rate of dissipation of energy initially increased with the extension of the crack and finally reached constant values. For ductile materials (larger CTOD), G_p became dominant (more than 70 percent of the total), whereas G_{rs} remained constant (about 6 percent). Furthermore, G_p appeared to vary linearly with the height of the plastic zone. G_s was found to be linearly proportional to the critical CTOD.



The **Total Rate of Dissipation of Energy,** G_T, consists of three components.

The observations made in this study are valid for other elastic-plastic fracture situations. For instance, the observations could apply to a very wide range of practical situations, including the growth of cracks in pressure vessels in nuclear powerplants.

This work was done by Kunigal N. Shivakumar of Analytical Services and Materials, Inc., and John H. Crews, Jr., of **Langley Research Center**. *Further information may be found in NASA TM-89032 [N88-26566], Price Code: A03 "Energy Dissiipation Associated With Crack Extension in an Elastic-Plastic Material."*

Copies may be purchased from the National Technical Information Service, Springfield, Virginia 22161, Telephone No. (703) 487-4650. Rush orders may be placed for an extra fee by calling (800) 336-4700. *LAR-14025/TN*

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NASA Tech Brief
National Aeronautics and
Space Administration

Experiments on Active Members in Large Space Structures

Built-in sensors and actuators monitor and control vibrations.

A report discusses continuing research on structures that include active members, which incorporate sensors, actuators, and electronic circuits to monitor and control vibrations. It describes experiments on two structures with active members as well as progress in the design, testing, and simulation of the behavior of active members. The long-term objective of this research is to develop systems to enhance the performances of large, flexible structures in space. The research may also be applicable to some terrestrial structures and testing equipment that involve close tolerances in the feedback control of forces and/or positions.

The active members of the test structures are equipped with various sensors and piezoelectric actuators to sense and control displacements at the micron level. Work is in progress to evaluate and adapt commercially available piezoelectric devices and to develop and test special in-house designs to optimize performance.

One of these structures is a 5-ft-long (1.5-m-long) segment of Astro-Mast, a long, narrow truss structure. Its base is cantilevered in a specially designed statically determinate interface. The six base reaction forces are supported by six struts that are flexured at each end so that they take only axial loads. The six struts are removable and can be easily replaced with active members. The active members will be used as vibration exciters to perform a system-identification test and establish a transfer-function model for the purposes of control. The Astro-Mast structure will also be used as a dynamic calibration fixture. This structure is intended to answer the following fundamental questions: How do piezoelectric active members behave as part of a structure, and can the active members be used for in situ system-identification testing?

The other test structure, called the Precision Truss, resembles truss-structure components for future astrophysics observatories in space, such as large segmented mirror telescopes and optical interferometers. This structure has been designed for maximum versatility. The six-bay, four-longeron statically indeterminate truss is approximately 6 ft (1.8-m) tall and is built up of ¼-in. (6.4-mm) aluminum tube struts connected to 1½-in. (38-mm) diameter aluminum joints. Each joint has a 26-hole pattern that can support a wide variety of truss geometries. Each strut is fitted with a custom-designed connector that allows it to be removed and replaced without disassembling the truss. In this way, active members can be easily retrofitted into any location on the structure. The base of the structure is cantilevered from a steel block weighing approximately 1,000 lb (454 kg).

Closed-loop controllers have been implemented using a high-speed digital control computer. The steady-state response of the truss to sinusoidal disturbances was reduced by 35 db, and the settling time was reduced by a factor of 30. The results of these preliminary tests suggest that control by active-members may provide unprecedented performance and adaptability.

This work was done by James L. Fanson and John A. Garba of Caltech for **NASA's Jet Propulsion Laboratory.** *"Experimental Studies of Active Members in Control of Large Space Structures."*
NPO-17623/TN

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NASA Tech Brief
National Aeronautics and Space Administration

Flexible Animation Computer Program

Vibrations, thermal distortions, and stresses are animated in color.

Heat, radiation, vibration, and stress can all influence the structure of a spacecraft. FLEXAN (Flexible Animation) is a computer program that animates structural dynamics on an Evans and Sutherland PS300-series graphics workstation with a VAX/VMS host computer. A typical application of FLEXAN, which was developed for the Spacecraft Analysis Branch of NASA's Langley Research Center, is the animation of a spacecraft undergoing structural stresses caused by thermal and vibrational effects. The animation displays the distortions in the shape of the spacecraft. Changes in the colors of elements in the display represent variations in temperature.

FLEXAN can display a single natural mode of vibration, a mode history (multiple modes), or any general deformation of a flexible structure. Elements of a structure can be animated through changes in color to reflect thermal information, stresses, etc. Selected parts of a structure can also be rotated through time. FLEXAN does not generate structural geometries or calculate any influences on structures; it displays only data generated from other computer programs and/or experimental data.

A structure is represented on the workstation as a three-dimensional wire-frame object. Solid objects or raster representations are not supported by this program. The VAX/VMS computer calculates the animation frames and sends them to the workstation. The workstation displays these frames in real time. Rotation, scaling, and translation are provided by the dials of the workstation. The workstation is not a true real-time machine, but it does provide a very close approximation. The animation can be displayed forward or backward at 1 to 50 frames per second or stepped 1 frame at a time. The speed of animation is controlled by a dial and two function keys. Other function keys toggle on and off various parts of the display or enable different views of the structure.

FLEXAN is capable of animating two independent sets of data in separate windows on the workstation. An optional third window displays a superposition of the two sets of data. This capability is useful for displaying the differences between design iterations or displaying sets of analytical versus experimental data. A large number of nodes and/or elements (over 200), a large number of animation frames (over 1,000), and the use of color require large amounts of memory. The FLEXAN examples are based on the assumption that a PS390 with 4 MB is available.

FLEXAN was written in FORTRAN77 and is specific to the Evans and Sutherland PS300 family of graphics workstations. It was implemented on a VAX/VMS computer system. The program requires a virtual memory of about 15 MB without the link libraries. FLEXAN was developed in 1989.

This program was written by Scott S. Stallcup of Computer Sciences Corp. for **Langley Research Center.**
LAR-14102/TN

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NASA Tech Brief
National Aeronautics and Space Administration

Licensing Opportunity

Laser Velocimetry in Low-Speed Wind Tunnels

Airflow velocity is measured with minimal perturbation.

The design and the performance of a three-dimensional and of a two-dimensional backscatter laser velocimeter, both used in low-speed (less than 100 m/s) wind tunnels, are described in a report together with a historical overview of the development of laser velocimetry (LV). LV provides measurements of airflow in wind-tunnel tests without the perturbing effects of probes and probe-supporting structures. LV may also be applicable in such related fields as ventilation engineering and possibly in the detection of wing vortexes from large aircraft at airports.

The three-dimensional laser velocimeter has been optimized for use in a wind tunnel having test-section dimensions of 7 by 10 ft (2 by 3 m). It measures all three velocity components by means of three independent dual-backscatter channels at argon-ion laser wavelengths of 514.5, 488.0, and 476.5 nm.

The test point is positioned by movement of the entire instrument package on a digitally controlled platform and by the variable focusing of zoom optics. A high-speed minicomputer controls the stepping motors that move the package, the data transfer among the devices of the system, and the reduction of experimental data. To facilitate decisions for the operation of the system, a graphics display plots the reduced data as a function of position as the velocimeter scans over a range of test points. The system also displays histograms and sample statistics for immediate feedback to the experimenter.

The long-range laser velocimeter has a measurement range of 2.6 to 20 m and uses an 18 W argon-ion laser. It will be installed in a wind tunnel having test-section dimensions of 40 by 80 ft (12.2 by 24.4 m). The optical system is mounted in a streamlined optical package in the wind-tunnel test section. The test-point position is varied by the lateral motion of the instrument along rails on the tunnel floor, by mechanical rotation of the instrument, and by the variable focusing of zoom optics within the optical system.

The instrument includes an onboard microprocessor controller and digital motor-control hardware. This unit is connected to the control electronics in the wind tunnel control room. The velocimeter can be positioned by automatic or manual control. In either mode, the control circuitry displays the test-point position in wind-tunnel coordinates and the measured velocity.

This work was done by Kenneth L. Orloff, Philip K. Snyder, and Michael S. Reinath of **Ames Research Center**. *Further information may be found in NASA TM-85885 [N84-16526], Price Code: A02 "Laser Velocimetry in the Low-Speed Wind Tunnels at Ames Research Center."*

Copies may be purchased from the National Technical Information Service, Springfield, Virginia 22161, Telephone No. (703) 487-4650. Rush orders may be placed for an extra fee by calling (800) 336-4700.

Inquiries concerning rights for the commercial use of this invention should be addressed to the Patent Counsel, Ames Research Center. Refer to ARC-11564/TN.

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NASA Tech Brief
National Aeronautics and Space Administration
Marshall Space Flight Center, Alabama

Licensing Opportunity

Offset Joint for Segmented Pressure Vessel

A slight offset reduces joint gap under pressure.

A concept for increasing the reliability of a segmented pressure vessel has been proposed. According to the concept, an inward offset of the tang and clevis bands of the encircling joint between segments can reduce or eliminate the gap that opens between the tang and inner leg of the clevis in response to pressure in the vessel.

The concept is an outgrowth of an analysis of the Space Shuttle Challenger accident. The analysis showed that when the 12-ft (3.66-m)-diameter solid-rocket case was pressurized by the burning solid fuel, the bulging wall rotated the tips of the tang and clevis outward, increasing the gap between the tang and the clevis. At an internal pressure of 936 lb/in.^{2} (6.45 MPa), the gap is 0.052 in (1.32 mm). The opening of the inner gap, which carried the O-ring seals, is believed to have contributed to the failure of the segmented joint.

A slight inward offset, however, creates a moment arm under pressure that compresses the tang and clevis and tends to close the gap. A finite-element analysis program, SPAR, was used to analyze the effects of geometry in the proposed offset joint. An offset of 0.5 in. (1.27 cm), for example, would reduce the gap to 0.025 in. at the stated internal pressure. For the same pressure, an offset of 1 in. would create interference of 0.006 in. (0.15 mm) between the tang and clevis.

This work was done by Carleton J. Moore of **Marshall Space Flight Center.** *No further documentation is available.*

Inquiries concerning rights for the commercial use of this invention should be addressed to the Patent Counsel, Marshall Space Flight Center. Refer to MFS-28365/TN.

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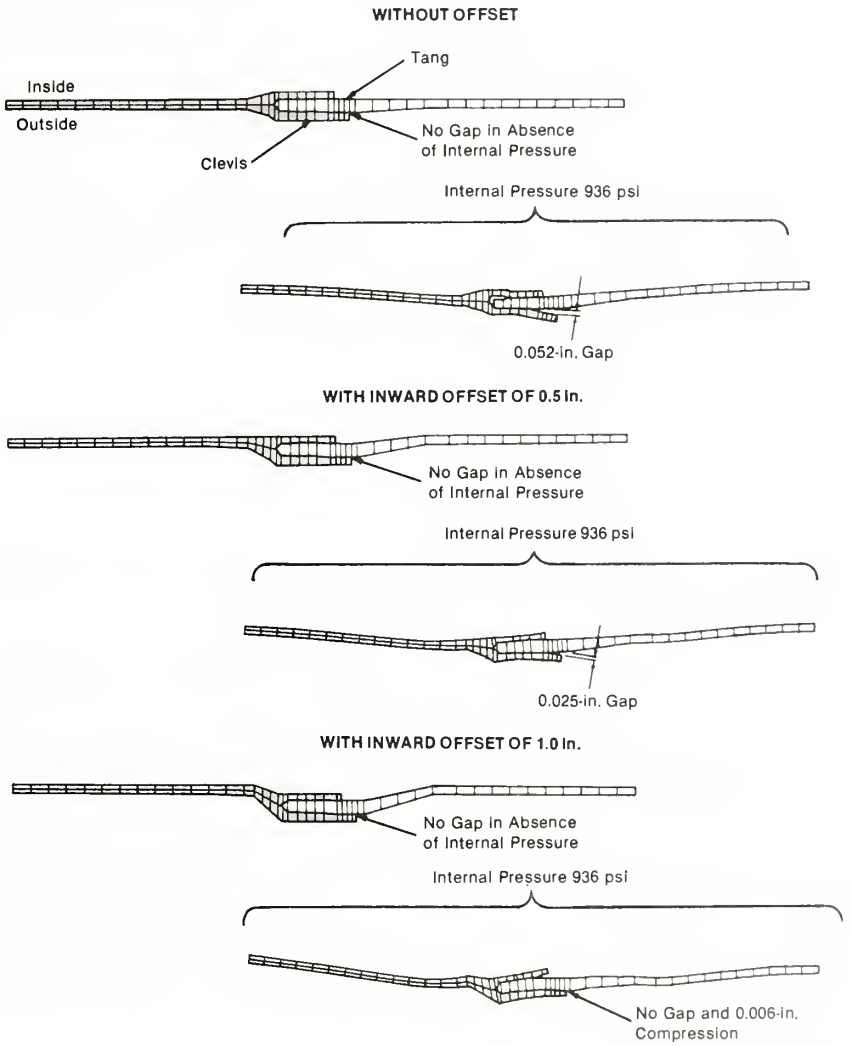

Internal Pressure causes a gap to open between the tang and clevis portions of a circular-band joint between cylindrical segments of a pressure vessel. The amount of opening can be reduced or eliminated by designing the tang-and-clevis band to have an initial (when unpressurized) inward offset.

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NASA Tech Brief
National Aeronautics and Space Administration
NASA's Jet Propulsion Laboratory, Pasadena, California

Precise Hinge Has Low Friction

Blade-in-groove rotation allows free movement through a limited arc.

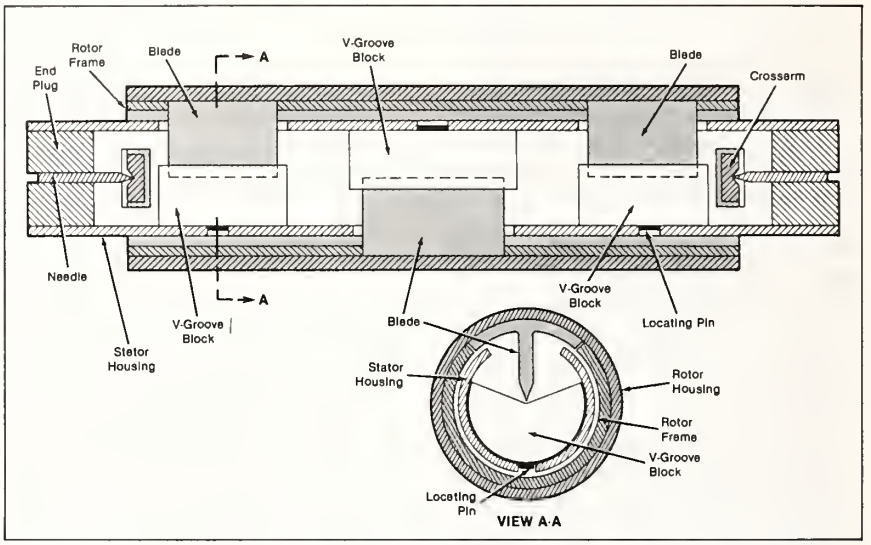
A precise hinge rotates with minimal friction and without "slop" — a deadband of loose, ineffectual movement at the beginning or end of rotation. The hinge is based on knife blades turning in grooves. The axis of rotation is at the central axis of a concentric, self-retaining assembly. The blades are in the same plane, and both the edges of the blades and the apexes of the grooves lie along the same line, allowing free rotation without either binding or slop.

A middle blade rests in a V-groove in a block, as do two flanking blades pointing in the opposite direction (see figure). In the view along the axis, blades are T-shaped with curved tops that fit in a rotor frame and rotor housing. A blade makes contact with a V-groove only at its edge; hence, the low friction.

The assembly of the hinge begins with the insertion of the three groove blocks into a stator housing, where they are retained by locating pins. The rotor frame is slid axially over the stator housing. The knife blades are inserted through cutouts in the rotor frame; the curved arms of the blades form a continuation of the cylindrical body of the rotor frame and fill the cutouts so as to keep the blades in place.

Finally, the rotor housing — a contiguous cylindrical shell — is pressed axially over the rotor frame. It locks the blades in the frame and holds the entire assembly together.

For mounting purposes, the stator-housing tube projects axially beyond the rotor-housing tube at both ends. The projecting ends of the stator can be press-fit or fastened by setscrews to bores in a mounting frame. The rotor-housing tube can be similarly fastened to rings on the object to be pivoted.



Blades on the Rotor Engage Grooves on the Stator. Blades can pivot about their edges through an arc defined by slotted openings in the stator housing.

Point-contact stops at both ends prevent axial movement of the hinge without adding significant friction. End plugs on the stator housing hold needles that make contact with conical holes in crossarms mounted on the rotor frame. Slots in the stator housing allow the crossarms to move with the rotor through a limited arc.

The hinge creates no centering or restoring torque; therefore, the rotor stays in its new position when rotation stops. If return torque is needed, a simple coil spring can be wound around the rotor, with one end connected to the rotor and the other to the stator.

This work was done by Earl R. Collins, Jr., of Caltech for **NASA's Jet Propulsion Laboratory.** *NPO-17749/TN*

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NASA Tech Brief
National Aeronautics and Space Administration
Lyndon B. Johnson Space Center, Houston, Texas

Simulating a Massive, Mobile Structure

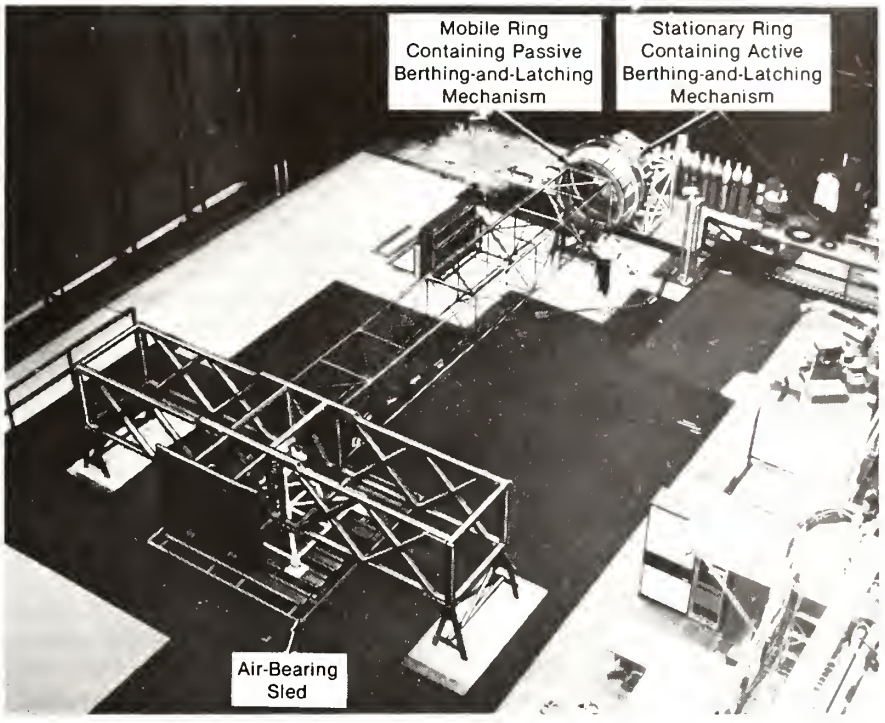
The mass of the mobile structure can be varied.

A simulator replicates, kinematically and dynamically, the mating of a large, massive mobile structure with a similarly large and massive fixed structure. The simulator was developed for testing a berthing-and-latching mechanism.

The simulator consists of a fixed section and a mobile section, representing the fixed and mobile structures (see figure). The fixed section holds an active berthing-and-latching mechanism and its motor control system with an optical encoder to maintain synchronization among the four latches in the mechanism. A tripodal load-cell network gathers data on the load history of a berthing operation, and an infrared tracking system that includes light-emitting diodes produces data for the position history.

The mobile structure holds a 30,000-lb (13,600-kg) passive berthing mechanism. It is a truss structure on a large sled supported by air bearings. A large spherical roller bearing between the truss and its support provides two degrees of freedom of movement. The sled provides an additional three degrees of freedom. The mass of the mobile structure can be varied by adding 500-lb (227-kg) ballast plates. The ballast plates can be arranged in a variety of configurations to alter the distribution of mass.

For a berthing test, the air bearings on the sled are activated, and the mobile structure is placed in various orientations with respect to the fixed structure, within the 4-in. (10.1-cm) reach of the latching mechanism. A test is completed when the four latches have linked the mobile structure to the fixed one.


Mobile Ring Containing Passive Berthing-and-Latching Mechanism
Stationary Ring Containing Active Berthing-and-Latching Mechanism
Air-Bearing Sled

The **Mobile Truss** is cantilevered from the sled-based structure at the left. The sled moves on air bearings supplied through the snaking tube on the floor. The fixed structure (behind the man) holds the active berthing-and-latching mechanism in the large ring.

This work was done by Peter M. Fantasia, Jon B. Kahn, and Benny B. Sprague of **Johnson Space Center.**
MSC-21482/TN

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REFER TO THE NUMBER LISTED AT THE END OF THIS ARTICLE

Capillary Pumped Loop Modeler

This program simulates the thermodynamic performance of capillary pumped loops.

The Capillary Pumped Loop (CPL) Modeler computer program is an amalgamation of software that mathematically models the performance of a CPL system and its environment. A CPL is a two-phase heat-transport device capable of transferring heat loads efficiently over a large distance with little temperature differential. It utilizes the surface-tension forces established in a fine-pore capillary wick to circulate the working fluid, thus requiring no external pumping power.

This program predicts the steady-state or quasi-steady behavior of a CPL embedded in a spacecraft or other thermal environment. It also predicts the location of the liquid/vapor interface in each condenser. The program calculates the pressure drops due to flow losses in various flow regimes including laminar, transition, and low- and high-Reynolds-number turbulent flows. The effects of subcooling on the liquid returning to the evaporator and of reverse flows in the evaporator associated with the sharing of heat loads are accounted for. The user can include multiple parallel evaporators and condensers. Thermodynamic properties of 20 fluids — including water, ammonia, propane, and propylene — are included in a library.

The modeler creates SINDA statements that describe the CPL from the parameters entered by the user into a user-friendly interface program. These statements are then combined with an environment the user generates in SINDA to create a complete analytic model of CPL. The operation of the CPL is then simulated as the merged input file is executed in SINDA.

The CPL modeler runs interactively on a VAX computer under VMS 4.4 or greater and is written in VAX/VMS FORTRAN 77. TAE (COSMIC program GSC-13017) executable is included on the tape. SINDA (COSMIC program MSC-20891) is included in this package but may not work in all versions. Process quota must be at least 20,000 and possibly higher. This program was developed in 1986.

This program was written by Jentung Ku and Elliot Itkin of OAO Corp. and Russell B. Schweickart and Laura Ottenstein of **Goddard Space Flight Center.** *GSC-13145/TN*

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Department of Energy

Technology Application

Lawrence Berkeley Laboratory

New Software Monitors System Behavior, Detects Deviations and Diagnoses the Possible Cause

Researchers have built a software system that locates faults in complex machinery. The system is called FindIt. It detects failures by monitoring the system's output data streams. Upon operator request, FindIt then uses a high performance data base to instantly trace the failure back to the components most likely to have caused the failure. The software is based on well established technologies including statistical testing, graph theory, set theory, data set organization, and a "software bus."

Successful operation of a manufacturing plant or a chemical-production plant requires the reliable operation of hundreds of thousands, even millions of complex components. Monitoring each individual component is usually too costly to consider. Therefore, the failure of a single component may be difficult to trace, especially since the effect of the failure may not be detected at a point that is near the failed component.

The inability to quickly diagnose the causes of failure in a complex manufacturing process can result in costly downtime. Current process monitoring systems are designed to detect the occurrence of a problem, but few are capable of identifying failed components when the possibilities number more than a few thousand.

The ability to quickly find and diagnose a complex-system error translates to large savings in process control and factory automation - reduced downtime, improved quality control. FindIt also builds confidence. There is never a doubt about the system, because the software provides a dynamic overview of the entire process.

As a proving ground for this technology, FindIt was applied to a particle detector (the HISS Time of Flight Wall) that has several thousand "breakable" components and over seven hundred output channels.

The project achieved significant breakthroughs on two levels: At the end user level, it produced a system that can monitor a variety of running equipment (not just detectors) and identify malfunctioning components in real time. At the software engineering level it produced a collection of reusable software components that can be applied to general scientific computing problems. This makes the system especially easy to adapt to new environments.

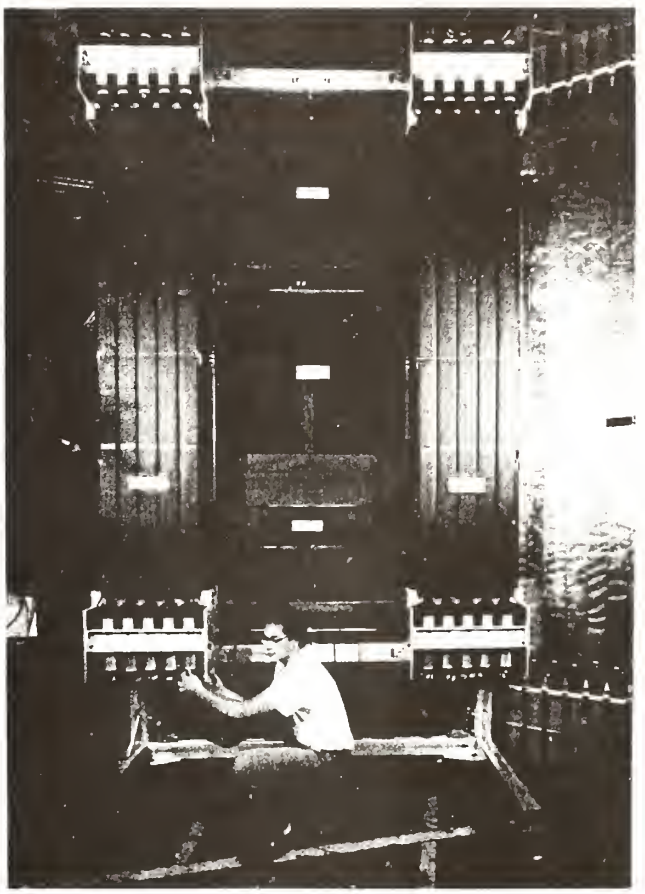


Figure 1. LBL's fault location system for complex processes detects online machinery failures by monitoring the system's output data streams. The system was applied to the HISS Time of Flight Wall particle detector to test the technology. An LBL researcher checks the detector's photomultiplier circuits prior to a data collection run.

Potential industrial applications for LBL's FindIt system include chemical process control, testing of electronic circuit boards, factory automation, software debugging.

Beyond its ability to diagnose running equipment, the fault location system has the potential to be used to help produce more reliable equipment designs. The fault identification mechanism can readily be reconfigured to predict the ease with which a proposed design can be diagnosed.

For the software itself, the bus approach offers industry a way to combine software products from different vendors without compromising the competitive advantage of either party. It is particularly easy to adapt the system to new applications. The fault location system is scalable to applications having millions of components.

Marketed as an added benefit to improve the manufacturing process, FindIt can help save time and money in the following areas: companies that need instrumentation or chemical process control, companies involved with large communications networks, software companies already involved in computer integrated manufacturing, manufacturers of power grids, integrated circuit manufacturers.

Technology benefits: on-line detection of faulty components; easy adaptations to new experimental conditions and equipment setup; high confidence that the experiment is operating correctly; large potential savings in process control and factory automation; reduced down time: better equipment design, earlier fault detection, faster fault diagnosis; improved quality control: better overall picture of processes, increased confidence; FindIt software is highly generic and flexible: easy to incorporate a new device, easy to change existing device.

Development status: Cost to produce an industrial-quality demonstration model is estimated at one-man year, Registered copyright.

FOR ADDITIONAL INFORMATION: FindIt is available for licensing from Lawrence Berkeley Laboratory. For further information contact: Mark Owens, Technology Transfer Office, Lawrence Berkeley Laboratory, 1 Cyclotron Road, Mail Stop 90-1076, Berkeley, CA 94720; (415)486-6463.

New Technology from the U.S. Bureau of Mines

U.S. Department of the Interior

Vehicle to Clean and Inspect Mine Track

Objective

Reduce the potential of haulage related injuries in underground mines by providing a method for quickly assessing the state of repair of mine haulage track.

The Problem

Currently, there are no established standards or procedures for inspection or cleaning of underground mine haulage track. Many track defects are hidden from an inspector because of layers of dirt and debris on the ballast, spikes, fishplates, etc. When a visual inspection can be performed, it may be highly subjective, except for a few items that can be categorized or counted, such as missing bolts or spikes. Track inspectors may even become tolerant of defects that can gradually worsen. For these reasons, mechanical inspection methods are needed to supplement visual inspections.

Approach

The Bureau investigated this problem and designed a towed vehicle to both mechanically clean and inspect underground coal mine haulage track. The vehicle was developed using a systems approach, paying particular attention to human factors issues such as operator field of view, operator ingress-egress, control positioning, and seating design. The prototype was built using simple fabrication techniques and off-the-shelf components.

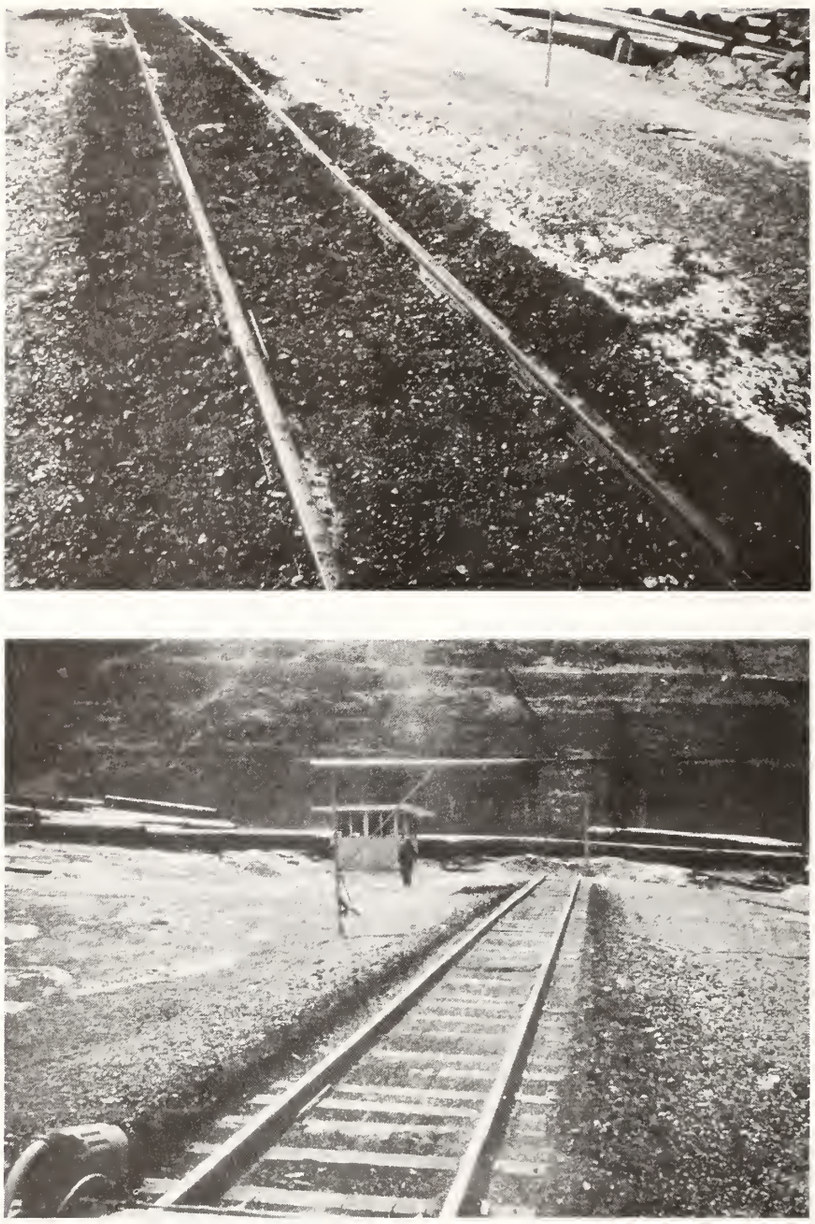
How It Works

The vehicle is a rail-mounted flatcar with a 36-inch-diameter hydraulically powered brush on one end. The rotating brush can clean track down to the level of the ties. Brush rotation speed varies from 0 to 125 rpm. The brush can swing 5° left or right to aid in cleaning switches and other track structures. The brush consists of a combination of polypropylene and steel wire bristles to provide stiffness and minimize matting.

The opposite end of the flatcar holds a mechanical track-measuring device. The device can measure both gauge and crosslevel based on changes in voltage as generated by a potentiometer and linear, variable differential transformer. The readouts from the measurement device are displayed on a gauge in the operator cab. An audible tone is emitted when user-specified limits are exceeded. The single, transversely mounted operator station is located in the center of the vehicle, allowing the operator a clear field of view in both directions. Power is received from the trolley system through a cable connection with the towing vehicle.

Test Results

The vehicle was tested on the surface at the Bureau's Lake Lynn Laboratory and in an underground coal mine. The results showed the rotating brush to be capable of cleaning underground mine track to the point where visual inspection is possible. The track measuring device also performed well. Both gauge and crosslevel were accurately measured.



Test track before cleaning (top) and after cleaning (bottom). Run-of-mine material that was lightly packed down on the track for the test was deposited at the sides of the track after the test.

For More Information

Details on the design, fabrication, and testing of the mine track cleaner-inspector are available in Bureau of Mines Report of Investigations (RI) 9246, "Underground Coal Mine Track Inspection and Cleaning Vehicle." For a free single copy of this RI, write to the Bureau's Publication Distribution Section, Building 149, P.O. Box 18070, Cochrans Mill Road, Pittsburgh, PA 15236-0070.

Additional details concerning the research are available from—

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U.S. Bureau of Mines
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Pittsburgh, PA 15236-0070
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NASA Tech Brief
National Aeronautics and Space Administration
Marshall Space Flight Center, Alabama

Licensing Opportunity

Radial Profilometry

Inner surfaces of tubes and tubelike cavities are measured optoelectronically.

Radial profilometry, now undergoing development, is a combination of optical and electronic techniques for the measurement of the inner surfaces of cylindrical or nearly cylindrical cavities. The main advantages of a radial profilometer are that it is relatively simple, inexpensive, and easy to use; it can be miniaturized; the profilometer probe contains no moving parts; the image is displayed continuously in the image plane; and measurements are automated. Potential applications include the inspection of pipes, tubes, and boreholes, and possibly the measurement of contours in blood vessels or other internal organs.

Figure 1 illustrates the optical configuration of a radial profilometer. A diverging laser beam launched from an optical fiber passes through a projection lens, then through a specially designed "panoramic doughnut" lens to a masked collimating lens, which shapes the beam into a thin cylinder. The cylindrical beam is reflected from a conical mirror to form a ring of illumination on the inner surface of the cavity to be measured. The image of the illuminated surface is captured by the panoramic doughnut lens and focused via the projection lens onto the face of a coherent bundle of optical fibers. The bundle transmits the image to a computer system for analysis.

The panoramic doughnut lens forms an image in flat cylinder perspective, in which each concentric ring is the locus of points viewed at a constant angle with respect to the cylindrical axis of the profilorneter (left part of Figure 2). There are several alternative procedures for processing the information in such an image. For example, one could initially establish a fixed coordinate system of reference marks in a portion of the cavity known to be precisely cylindrical, then calculate small deviations from cylindricity in other portions of the cavity in terms of the nonlinear relationships among the coordinates in the distorted image and the coordinates in the cavity. The profilometer could be moved along the cavity to obtain a sequence of images that could be processed collectively to yield the coordinates of the inner surface along a specified length.

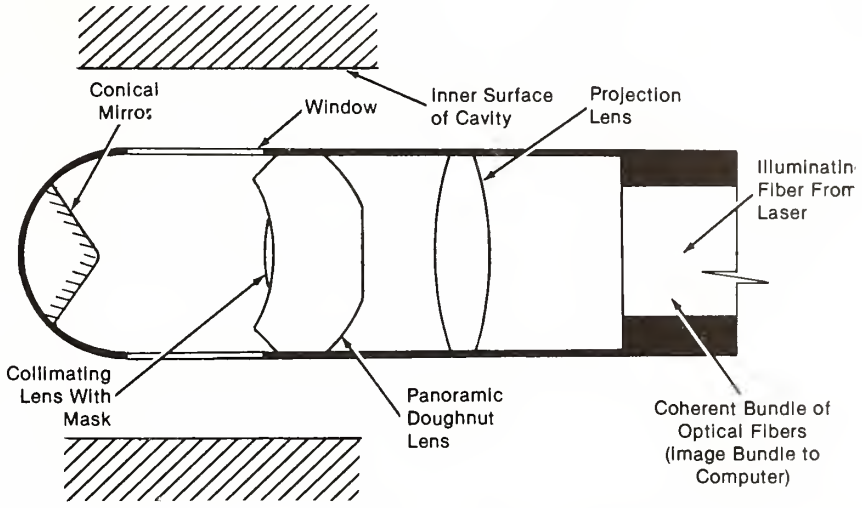

Figure 1. The **Radial Profilometer** is inserted in a pipe or other cavity to measure its shape optically. Illumination is supplied through an optical fiber, and the image of the inspected area of the cavity is transmitted through a bundle of optical fibers.

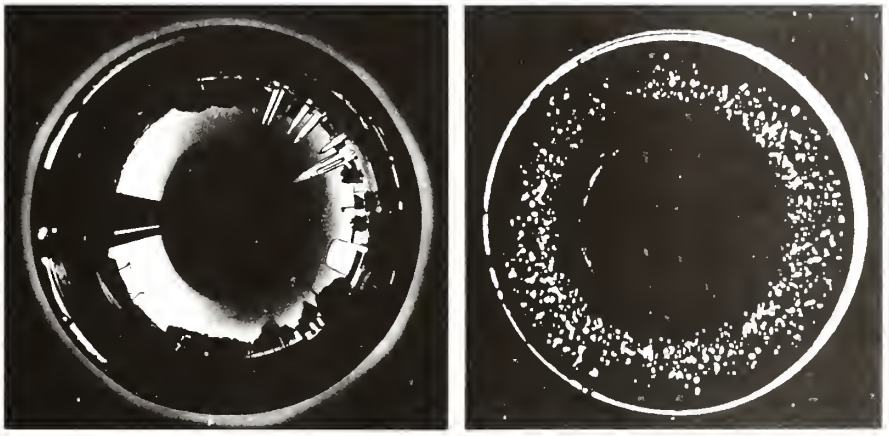

Figure 2. **Flat Cylinder Perspective** is illustrated by the image at the left, which was obtained by pointing the panoramic doughnut lens at the sky at Huntsville, Alabama's Space and Rocket Center. A speckle pattern like the one shown on the right image, also in flat cylinder perspective, can be compared to a reference pattern to measure the shape of a nearly cylindrical inner surface.

Work continues to develop a more advanced version in which a known speckle pattern, instead of a homogeneous ring of light, is projected on the surface to be measured (right part of Figure 2) and in which the profilometer remains stationary. The speckle pattern in the resulting image would be digitally recorded and compared either with a reference standard or with other speckle patterns recorded as the shape of the cavity changes. The apparent shifts of the speckle would be computed by numerical correlation of small portions of each pattern. These shifts would be used to compute the contour of the cavity with respect to the reference shape.

This work was done by J.A. Gilbert, P. Greguss, and D.R. Matthys of the Univer-

sity of Alablama for **Marshall Space Flight Center.**

Inquiries concerning rights for the commercial use of this invention should be addressed to the Patent Counsel, Marshall Space Flight Center. Refer to MFS-26101/TN.

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NASA Tech Brief
National Aeronautics and Space Administration
Langley Research Center, Hampton, Virginia

Licensing Opportunity

Schlieren System for Flow Studies in Round Glass Pipes

Cylindrical lenses compensate for refraction in the walls.

In a schlieren system for studying the flow of a gas in a transparent pipe of circular cross section, cylindrical lenses placed on opposite sides of the pipe compensate for the refraction caused by the wall of the pipe. In a typical schlieren system, a parallel beam of light produced by a point light source and collimator passes through the test cell. A second collimator operating in reverse then focuses the beam back to a point. A knife edge is placed at that point, so that it grazes the beam, cutting off about half the light. Variations in the flow of gas give rise to gradients in the index of refraction, which deflect the beam slightly as it passes through the test cell. As the beam passes the knife edge, those deflections are translated into variations in intensity. The intensity decreases or increases, depending on whether the deflection of the portion of the beam from a given region in the test is toward or away from the knife edge, respectively.

If the test cell is a circular pipe, the wall of the pipe acts as a slightly diverging lens. Therefore, in this system (see Figure 1), the first cylindrical lens causes the beam of light entering the pipe to converge just enough that the rays of light become parallel again as they reach the interior of the pipe. As the light leaves the interior of the pipe on the opposite side, the wall again introduces a slight divergence, and the second cylindrical lens reconverges the rays to parallelism. Figure 2 shows a schlieren photograph taken with the new system. Such schlieren visualization supplements other flow data like measurements of velocity, pressure, and temperature.

The new system enables direct visualization of such phenomena as laminar or turbulent flow, shock waves, vortexes, and flow separations in systems that have inherently cylindrical geometry; potentially unreliable extrapolations from results in flat-sided test cells are no longer necessary. For example, secondary flows caused by joints and elbows in circular pipes are different from those in rectangular pipes. Also, turbulence can be reduced unrealistically near the corners in rectangular test cells, and transitions between circular and rectangular cross sections can cause flow anomalies.

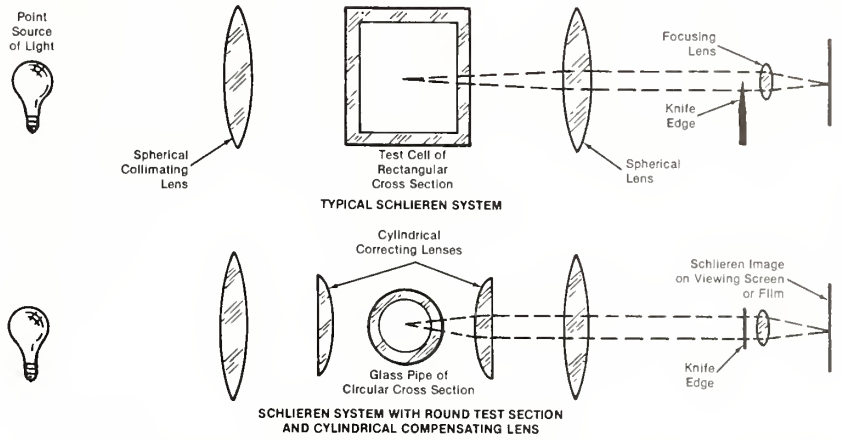
Point Source of Light
Spherical Collimating Lens
Test Cell of Rectangular Cross Section
Focusing Lens
Knife Edge
Spherical Lens
TYPICAL SCHLIEREN SYSTEM
Cylindrical Correcting Lenses
Schlieren Image on Viewing Screen or Film
Glass Pipe of Circular Cross Section
Knife Edge
SCHLIEREN SYSTEM WITH ROUND TEST SECTION AND CYLINDRICAL COMPENSATING LENS

Figure 1. In a **Typical Schlieren System** (above) the test cell has flat sides, which do not focus or defocus the beam of light. The new schlieren system (below) for studying flow in a pipe of circular cross section includes two cylindrical lenses that compensate for the refraction that occurs in the wall of the pipe.

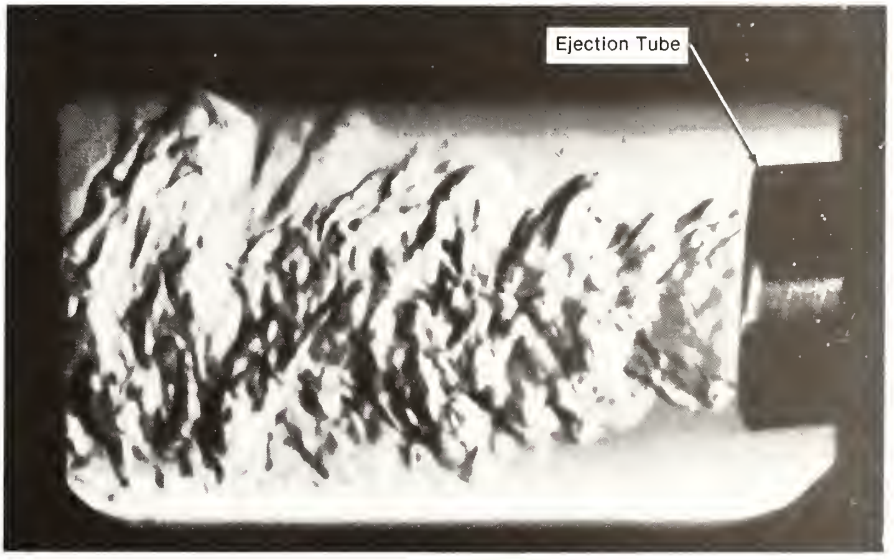

Figure 2. The **Flow of a Dense Chlorofluorocarbon Gas Into Air** in a glass pipe was photographed with the new schlieren system.

Because of residual refraction errors caused by the cylindrical components, the spot focused on the knife edge is smeared slightly in the direction perpendicular to the axis of the test cell. To avoid the effects of this smear, the knife edge in the new system must be oriented perpendicular to the axis of the test cell.

The cylindrical optical components introduce some lateral magnification, so that the final image appears slightly stretched in the direction perpendicular to the axis of the pipe. The ratio between the longitudinal

and lateral magnifications can be determined by placing a grid or other object of known dimensions in the tube and making appropriate measurements on the resulting schlieren image.

This work was done by Robert C. Costen, David B. Rhodes, and Stephen B. Jones of **Langley Research Center.**

This invention is owned by NASA, and a patent application has been filed. Inquiries concerning nonexclusive or exclusive license for its commercial development should be addressed to the Patent Counsel, Langley Research Center. Refer to LAR-13944/TN.

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Environmental Science & Technology

0169 Applications of Fluids Modeling to Assessment and Remediation of Hazardous Waste Sites

0170 Isolation and Identification of Microorganisms Capable of Degrading Common Laboratory Solvents

0171 Plasma Waste Treatment

0172 Navy Studies Nonpoint Source (NPS) Pollution

Testing & Instrumentation

0173 Mercury Analysis to Meet Water Quality Criteria

0174 Supercritical Oxidation Destroys Aqueous Toxic Wastes

Other Items of Interest

0154 Oil Water Separation Made Easier by Using Nonpersistent Emulsifying Degreasers

0212 Computerization of the Decisionmaking Framework for Management of Dredged Material

Technology Application

Idaho National Engineering Laboratory

Applications of Fluids Modeling to Assessment and Remediation of Hazardous Waste Sites

Contaminant migration from hazardous waste sites, spills, and subsurface tank leaks is becoming an increasingly significant cause of groundwater pollution problems. Environmental regulations such as RCRA require three basic types of environmental restoration activities: characterization of the contaminated site, assessment of the impact of the waste migration, and design and implementation of remedial actions. Fluids modeling techniques can play a significant role in each of these activities.

Because of the high costs of site characterization, there is an incentive to use a quantitative (rather than a trial-and-error) approach to guide the data collection process. Using baseline characterization data, fluids modeling can be used to determine the number and location of new boreholes needed to adequately characterize the contaminated site. Computer simulations of contaminant plume movement are typically used to determine the locations where field data will provide the most information regarding plume migration and fate.

An initial assessment of the potential impact of contaminant movement is an important first step because it influences decisions regarding: (1) the site characterization, (2) time limit available to implement site clean-up and (3) selection of remediation techniques(s). The initial assessment can be performed using fluids modeling techniques. Computer predictions of contaminant concentrations at receptor points (eg., public water wells, rivers or lakes) are used to determine if (and when) the plume may cause water quality regulations to be exceeded.

Remediation of large contaminated soil sites is generally achieved by some combination of: (1) soil removal, (2) soil-venting, and/or (3) groundwater extraction/treatment. Fluids modeling can be applied to evaluate the effectiveness of alternative remedial actions. The evaluation can lead to a restoration plan that minimizes site clean-up costs and clean-up time.

EG&G's Geosciences Unit has been involved in a number of restoration projects for hazardous waste sites. Three particular applications are highlighted here: (1) INEL's Radioactive Waste Management Complex (RWMC), (2) McClellan Air Force Base, and (3) Eglin Air Force Base.

A major portion of the *INEL's RWMC facility* is classified as a mixed waste. Pits and trenches in the RWMC contain a mixture of transuranic and organic wastes (i.e., chlorinated solvents). The volatile nature of organic wastes produced a subsurface vapor plume. Testing of groundwater samples showed that the plume reached the groundwater aquifer. Fluids modeling was applied to the "organics" problem at the RWMC to develop and evaluate remedial actions. Fluids modeling has been used to design the soil-venting system, locate monitoring wells and estimate clean-up times.

Located in Sacramento, California, *McClellan Air Force Base* has been a site of active remediation. The major cause of the hazardous waste problem at McClellan is due to past practices of organic liquid disposal in open pits. Organic contaminants such as trichloroethane, trichloroethylene, and other chlorinated solvents have contaminated a large portion of the aquifer beneath the site. Fluids modeling techniques were applied to design a groundwater extraction system.

Eglin Air Force Base is located on the west coast of Florida near Fort Walton Beach. Four different areas of the base are being studied to characterize groundwater contaminant plumes. There are two primary contaminants at these site: diesel fuel and trichloroethane. Fluids modeling techniques are being applied to estimate the migration rates of the plumes to nearby surface water features.

The Geosciences Unit has assembled a broad suite of computer codes for modeling fluids in the subsurface. Those codes are applicable to contamination problems associated with both the vadose (i.e., unsaturated soil) and groundwater zone. Single or multiple phase contaminants can be modeled in complex, heterogeneous, anisotropic geologic systems. The computer codes are interfaced with special graphics software that produce computer visualizations of the subsurface plumes. The computer codes are installed on the INEL's CRAY supercomputer which has two central processors and 16 million words of core memory. The large capacity and remarkable speed of the Cray supercomputer permit a very rapid analysis of hazardous waste contamination problems.

FOR ADDITIONAL INFORMATION: Mr. Robert G. Baca, EG&G Idaho, Inc., P.O. Box 1625, Idaho Falls, ID 83415; (208)526-1295/FTS 583-1295; and Bryant C. Hafen, Office of Research & Technology Applications, Idaho National Engineering Laboratory, P.O. Box 1625, Idaho Falls, ID 83415; (208)526-2883/FTS 583-2883.

Department of Energy

Technology Application

Idaho National Engineering Laboratory

Isolation and Identification of Microorganisms Capable of Degrading Common Laboratory Solvents

Organic compounds are produced in vast quantities in our highly industrialized society. These compounds serve a variety of needs and uses in many aspects of industry, medicine, agriculture, research, and government projects. Some of these organic materials are specialized, complex or polymeric, e.g., PCB, resins, synthetic polymers, pesticides, etc. Another group of organic compounds are produced in bulk quantities and are usually simpler in structure. These are categorized as solvents, chemical intermediates, monomers, carriers, etc. Many of these compounds are low-cost liquids and are discarded after use. These compounds are now showing up in the groundwater and soils as contaminants at levels beyond the limitations established by the regulatory agencies. Since these compounds can be very hydrophobic and nonionic, once they are introduced uncontained into the environment migration often occurs. Many sites have been identified as contaminated with these compounds.

Microorganisms play a significant role in the carbon, nitrogen, sulfur, and phosphorus cycles in nature. Some of these same microorganisms have metabolic pathways permitting the degradation of many of the previously cited organic compounds. Soil microorganisms, bacteria, and fungi have been shown to degrade compounds, e.g., hydrocarbons, aromatic and non-aromatic, halogenated and other substituted compounds. Increasing the rate of degradation has been accomplished by optimizing the growth conditions for the organisms versus the conditions that exist in the environment. Both research and development in bioremediation is underway in order to develop this technology for commercial use.

Few studies have explored the possibility of isolating organisms capable of degrading these organic solvents by their functional groups. If successful in both the isolation of organisms and in the process development for waste treatment, on-site disposal could be achieved. This would alleviate the storage, excessive handling, transportation, and possibly the reduction in cost for the toxic and hazardous wastes disposal.

Many facilities produce small quantities of a variety of waste solvents, e.g., university research labs, hospitals and quality labs. Some of the waste generated by these facilities is not only hazardous waste but a mixed hazardous waste. This type of waste contains both hazardous organics plus radioactive material. Limitation and restrictions are now in place that makes the disposal of this waste difficult. Therefore, much of this waste is presently being stored. Specialized microorganisms that can treat these wastes are being developed.

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Idaho National Engineering Laboratory

Plasma Waste Treatment

Plasma waste treatment uses intense electrical arcs to produce a high temperature gas that will destroy volitile organic compounds and melt metals and inorganics into a rocklike slag. The major advantages of plasma are the high power density which allows the use of relatively small reactors and minimizes the volume of off-gas. In addition, in contrast to fuel fired incinerators, the plasma gas can be oxidizing, reducing, or inert.

The INEL is investigating the use of plasma treatment for soils contaminated with organics and metals as well as ongoing waste streams. Soil treatment and melting experiments have been conducted in two types of plasma reactors in the last year. One of these reactors is installed at the INEL CDIF facility in Butte, Montana, and is part of a collaborative program between Retech (a private company), DOE, and EPA. The other soil treatment experiments took place at another private company, Plasma Energy Corporation (PEC), in Raleigh, North Carolina. These two plasma reactors are quite different in design; the INEL is interested in evaluating many plasma reactor designs to determine which ones are applicable to the various types of waste. It is not expected that a single design will be applicable to all types of waste.

Production plasma waste treatment reactors are expected to operate at power levels of one to ten megawatts with throughputs of one or more tons per hour per megawatt of power. Since electricity is expensive and there are large quantities of waste, it is important to maximize efficiency. Other important considerations are simplicity and ease of maintenance, since the reactors will be treating mixed wastes. Through the Butte, Montana, Facility, the INEL plans to develop plasma based waste processing technologies that are efficient, safe, and economic. This development work will be done at a plasma waste processing engineering development facility to be established at the site.

The production of titanium powder is another promising application of plasma technology. INEL researchers are developing a novel plasma reactor for the direct reduction of titanium tetrachloride to titanium powder at high yield. This reactor does not require metallic reductants. Development of this process will result in a significant cost savings in the manufacture of titanium powder.

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NAVY
Domestic Technology Transfer Fact Sheet

Navy Studies Nonpoint Source (NPS) Pollution

Water quality in many waterways and bays continues to decline even when point source discharges of pollutants have been eliminated. It is believed that nonpoint source (NPS) discharges are frequently the cause of the decline in water quality. NPS is the result of human activities such as construction, waste disposal, agriculture, silviculture, etc., occurring over a large area, rather than at a single point. Thus, the need to regulate NPS discharges has become evident.

The Naval Civil Engineering Laboratory (NCEL), Port Hueneme, California, has conducted a study examining various methods of assessing, monitoring, and controlling NPS pollution. The data collected can be used to develop strategies for complying with current regulations.

Methods of controlling NPS pollution are divided into two general categories: structural controls and land management techniques. Structural controls are designed to contain and/or displace NPS discharges followed by treatment and/or disposal of the contained pollutants. In certain situations improved land management techniques rather than mitigation with structural controls are required. New techniques are currently being tried, and NCEL is pursuing sites needing NPS control and mitigation for demonstration of emerging technologies.

For Additional Information:

Backup material on this effort is available from:

Navy Domestic Technology Fact Sheet Reader Reply Service
Code E211
Naval Surface Weapons Center
Dahlgren, VA 22448-5000
(703) 663-8921

Refer to 150404/TN

U.S. Army Corps of Engineers
Waterways Experiment Station
P.O. Box 631, Vicksburg, MS 39181-0631

Mercury Analysis to Meet Water Quality Criteria

The Corps of Engineers faces various problems at its projects in adhering to the 1986 Water Quality Criteria. The current methodology approved by the U.S. Environmental Protection Agency (EPA) for meeting requirements of the Clean Water Act does not provide detection limits capable of meeting these criteria.

Section 304(a)(1) of the Clean Water Act requires the EPA to publish and periodically update ambient water quality criteria and reflect the agency's recommendations on acceptable pollutant limits for aquatic life and human health protection. In 1986 these criteria were updated and a freshwater chronic criteria for mercury was set at 0.012 micrograms per litre (µg/L), and a marine chronic criteria was set at 0.025 µg/L.

The only method approved by the EPA for mercury analysis under the Clean Water Act is a flameless atomic absorption (AA) method, EPA Method 245.1 (EPA 1979), more commonly referred to as the Cold Vapor Technique. The procedure uses a 100-millilitre (mL) sample aliquot and attains a 0.2 µg/L detection limit. The detection limit may be lowered to 0.1 µg/L by doubling the sample aliquot, but it is not feasible to extend the procedure further without extensive procedure modification.

To obtain lower detection limits, Batelle has modified the method of Fitzgerald and Gill (1979) and has established it as a Standard Operating Procedure (SOP) for the Region II EPA Office of Marine and Estuarine Protection in support of their Sludge Site Monitoring Program. Mercury is reduced to the elemental state with stannous chloride and purged from the sample with nitrogen. Volatile mercury is collected on gold-plated quartz chips contained in a quartz column. The columns are thermally desorbed in a stream of nitrogen and the resultant mercury vapor is analyzed by Cold Vapor AA. The procedure lists a realistic detection limit of 0.2 nanogram (ng) of mercury using a Class 100 clean room for analysis. Because the method is so sensitive, it will be difficult to separate water concentrations for contamination at these low level concentrations in routine environmental monitoring program where external sources of possible contamination begin with the selection and cleaning of sample bottles and extend through the sample collection process and the transportation of samples to the laboratory.

Another procedure under investigation for determining these lower detection limits is a modification of a procedure using a Gold Film Mercury Vapor Analyzer (Jerome Instrument Corporation 1986). This instrument's method of detection is based on the characteristic that elemental mercury vapor will be adsorbed on a thin gold film, causing resistance changes in the film that are linear in nanogram concentrations (McNerney, Buseck, and Hanson 1972). The Jerome 511 Mercury Analyzer has a detection limit of 1 ng of mercury with a 10 mL sample size. In theory, a 100-mL sample aliquot should produce a detection limit of 0.01 µg/L which would meet the recommendations of the water quality criteria.

To investigate the possibility of lowering the detection limits, experiments were conducted at the U.S. Army Engineer Waterways Experiment Station using a Jerome 511 Gold Film Mercury Vapor Analyzer. Sample preparation for the Jerome 511 is also based on EPA Method 245.1.

A series of duplicate trials was run using volumes of 10, 20, and 30 mL of sample to determine the feasibility of using the Jerome 511 to analyze a greater volume of sample.

FOR ADDITIONAL INFORMATION: Environmental Laboratory, ATTN: J. L. Decell, U.S. Army Engineer Waterways Experiment Station, 3909 Halls Ferry Road, Vicksburg, MS 39180-6199; 601/634-3494.

Sandia National Laboratory

Supercritical Oxidation Destroys Aqueous Toxic Wastes

Scientists at Sandia National Laboratories' Combustion Research Facility in Livermore are studying a new technology for destroying aqueous toxic wastes. The technology - called supercritical water oxidation - shows promise for detoxifying the wastes in an efficient, cost-effective, and environmentally safe manner.

With a research program combining experimental, theoretical, and computer simulation efforts, researchers are shedding light on the basic chemical mechanisms underlying the supercritical water oxidation process.

"It's a whole new area of chemistry that remains an enigma," notes Sandia scientist Sheridan Johnston. "While industry has built a few experimental reactors to demonstrate feasibility of the technology, no one really knows what goes on inside a supercritical water reactor or how to scale up to commercial operation. We hope to change that situation and share our results with industry."

Supercritical water oxidation occurs at relatively low temperatures but moderate pressures (about 300 atmospheres and 500 degrees C - a temperature that is considered low when compared with the 2200 degrees C temperature of an open air flame). Under these conditions, water becomes a fluid with unique properties that can be used to selectively destroy organic wastes. For example, oils and chlorinated hydrocarbons become soluble for easy oxidation. Dissolved salts and metals also precipitate out of solution for fast and safe treatment and disposal.

This technology has been used for a few decades by the food industry to extract various materials such as caffeine from coffee beans and cholesterol from eggs and other dairy products. However, the concept of using supercritical conditions for oxidizing toxic materials - originated at the Massachusetts Institute of Technology by Professor Mike Modell - is only about 10 years old.

"Several qualities make supercritical water oxidation particularly attractive for the destruction of certain classes of toxic waste and preferable over other techniques such as incineration, storage in sealed containers, or injection into deep wells," says Johnson.

Oxidation of liquid toxic wastes under supercritical conditions generates very little air pollution. The final products are clean water, carbon dioxide, nitrogen, and metals and salts that precipitate out of solution and are collected without becoming airborne.

In addition to low-temperature oxidation of hazardous waste, it is also possible to create a flame in supercritical water without an external ignition source. The existence of such "hydrotherapy" flames was first demonstrated two years ago at the University of Karlsruhe in West Germany.

A supercritical water reactor designed by Sandia to investigate hydrothermal flames has been built and was the focus of recent series of experiments. Called the Supercritical Flame Reactor, it is designed to investigate the spontaneous formation of high-temperature (3000 degrees C) flames that can occur during supercritical water oxidation.

The goal of continuing experiments is to determine fundamental information concerning how variations in temperature, pressure, waste concentration, chlorine amount, and input rates affect the generation of hydrothermal flames. These data are particularly important because "hot spots" caused by the flames could weaken a supercritical reactor vessel and lead to pollution through high-temperature oxidation.

Such information will also show how a hydrothermal flame could be used to generate high temperatures to shorten reaction times, thereby allowing higher flow rates (and lower residence times) in the experimental reactor or more compact reactors.

The Sandia Supercritical Flame Reactor holds about 15 cubic centimeters (about three teaspoonfuls) of material. The reactor was constructed of a special nickel-based alloy called Inconel 718. This material permits the reactor to withstand the unusually harsh environment of supercritical solutions, such as high or low temperatures and pressures and corrosion from chlorinated compounds.

Viewing ports made of sapphire crystal permit direct viewing and video recording of supercritical oxidation reactions. They also allow laser diagnostic measurements to be made while reactions proceed. Conventional analytical chemistry techniques are being used to determine reaction products.

Sandia researchers are also designing a "supercritical flow reactor" to study high-flow, low-temperature (500 degrees C) supercritical combustion reactions. "Laser-based diagnostic techniques will be used to determine temperatures, concentrations of reactants, and the chemical kinetics of the reaction," says Steve Rice, who leads this project.

Complementing the experimental research is mathematical work to better understand the chemistry and reaction pathways of supercritical oxidation. There is a plan to model supercritical water oxidation using Sandia's Cray supercomputers and CHEMKIN computer software. (CHEMKIN is a code developed at Sandia in 1980 and now used worldwide for chemical kinetics calculations.) Computer simulation also could become an important tool for designing full-scale supercritical water oxidation reactors.

There are many potential applications for supercritical water oxidation of hazardous wastes.

Sandia researchers, together with scientists from Modell Development Company, a Massachusetts-based company, have recently demonstrated that supercritical water oxidation can remove organic components from mixed wastes and cleanly oxidize coal.

FOR ADDITIONAL INFORMATION: Public Information Division, Code 3161, Department of Energy, Sandia National Laboratories, Albuquerque, NM 87185-5800; (505)844-4207. Refer to announcement 25 No. 8.

Manufacturing, Machinery & Tools

0175 Blade and Disk Disassembly Machine
0176 High Strength, Flat Sheet Metal Abrasive Waterjet Cutting
0177 Laser-Assisted Thermoplastic Consolidation
0178 Machining Initiatives For Aerospace Small Subcontractors: Management Planning and Control Systems
0179 Automated Manufacturing Inspection System
0180 Tool Management for the Rock Island Arsenal
0181 Arc Reflector for Welding Ducts—The reflector is improved for use on round ducts.
0182 Compact Pinch Welder—An easy-to-use gun boosts productivity. (Licensing Opportunity)
0183 Increasing the Dexterity of Redundant Robots—Redundant coordinates are used to define additional tasks. (Licensing Opportunity)
0184 Integrated Process for Insertion and Beatup of Fill Yarns—This process works with angle-ply weaves. (Licensing Opportunity)
0185 Robust, high-Performance Control for Robotic Manipulators—Model-based and performance-based control techniques are combined. (Licensing Opportunity)
0186 Ultrasonic Abrasive Removal of EDM Recast—A form-fitted tool is vibrated in the presence of abrasive material.

Software

0187 Fault Location System

Testing & Instrumentation

0188 Holographic Wafer Inspection
0189 Enhancement of Penetrant-Inspection Images—Software makes flaws more apparent and creates a data base.

Other Items of Interest

0152 Directory Published on Weights & Measures Labs
0161 Offset joint for Segmented Pressure Vessel—A slight offset reduces joint gap under pressure. (Licensing Opportunity)
0165 New Software Monitors System Behavior, Detects Deviations and Diagnoses the Possible Cause
0195 Braided Composite Threaded Fasteners—Stronger fasteners would be made with less waste. (Licensing Opportunity)
0200 Treating Nickel Alloy for Sonic Quality—Bars are processed to enable acoustic monitoring of stress. (Licensing Opportunity)

Technology Assessment
U.S. Air Force

Blade and Disk Disassembly Machine

Mechanical Technology Inc. has developed a machine that automatically disassembles blades from gas turbine compressor disks. The blade and disk disassembly machine (BDDM) uses a combination of mechanization, automation, and operator involvement to accomplish the complex disassembly.

The BDDM process removes blades with a high speed impact hammer by aligning the hammer with each blade and striking the blade, which shears the retaining pin. Remnants of the retaining pins are then removed with a pin-removal device.

Prompts displayed on the system's video display guide the operator through the removal procedure. A video camera and display accomplish the precise alignment of the machine's electro-impact pin removers. After initial alignment, the system removes the blades and pins automatically.

The BDDM balances a number of conflicting design goals. For example, high level force is used to shear pins for blade removal as well as corroded pins without damaging delicate and precise engine parts. Even though operators are needed for machine setup, the BDDM's repetitive functions are fully automated.

Needs analyses and economic assessments were performed for BDDM implementation in 1986, the detailed design was completed in 1987, and the machine was built in 1988. System demonstration and a comprehensive pre-delivery test was performed in January 1989. After the BDDM was delivered to the San Antonio Air Logistics Center (SA-ALC) in February 1989, the system was thoroughly evaluated for use by Mechanical Technology Inc. and SA-ALC personnel.

The BDDM was installed at the SA-ALC in May 1989. SA-ALC personnel have been trained in its operation and maintenance. The BDDM has been in successful production ever since.

The BDDM has reduced cycle time for disk disassembly by more than 75 percent. For example, the T56 6th stage compressor disk requires 80 minutes for manual disassembly, but when the BDDM is used, the same compressor disk can be disassembled in 18 minutes.

More importantly, the scrap rate of 35 disks a month has been reduced to zero since the machine went into use. The projected saving from scrap is approximately $300 thousand a year.

FOR ADDITIONAL INFORMATION: To discuss this effort further, contact: Project Engineer: David See, Air Force Manufacturing Technology Program, ATTN: AFWAL/WRDC/MTPM, Wright Patterson AFB, OH 45433-6533; (513)255-3612. Refer to contract: F33615-86-C-5012.

Technology Assessment
U.S. Air Force

High Strength, Flat Sheet Metal Abrasive Waterjet Cutting

Aerospace sheet metal part manufacturing involves tremendous part variety and small lot sizes. For example, a typical aircraft manufacturer will fabricate 20,000 to 100,000 different kinds of sheet metal blanks, either as a finished flat part or a "cut-to-shape" blank. The majority of these parts are produced with dies using punch presses. Each part requires a unique die, which is costly and time consuming to fabricate or to modify in response to engineering design changes.

A significant amount of these parts are produced by second- and third-tier aerospace subcontractors; conventional methods for cutting flat sheet metal blanks and parts constitute one of their major costs for these parts. Adding to these costs, the use of titanium and high nickel steel alloys intensify flat part fabrication problems because these materials cause rapid tool wear and require high cost tooling material.

High temperature alloys are becoming more prevalent in the aerospace subcontractor environment with the development of new generation high performance aircraft and space vehicles. Furthermore, the cutting processes must be compatible with the electronics data transfer to accommodate computer integrated manufacturing that is being introduced to the aerospace industry.

Rohr Industries, Inc., a second-tier aerospace subcontractor, successfully implemented an abrasive waterjet (AWJ) cutting facility for cutting high strength, flat sheet metal. The cutting facility uses computer data base tooling and nested part programming. The project included the development of AWJ process parameters to control part quality for ten high strength sheet metal, the refinement of the AWJ process for cutting sheet metal, and the development of a cost benefit analysis of the installed system. The technical and cost data are being made available to second- and third-tier aerospace subcontractors for expanding and improving the subcontractor base.

The implementation of the computer numerical controlled (CNC) AWJ machine has solved many of the short comings of blanking operations. For example with computerized part nesting, the utilization of high cost part material has improved. The use of computer data base tooling permits the quick turn around of new orders in response to engineering changes. Hard tooling (unique dies for each part) and its associated material and maintenance costs also have been eliminated. Also the AWJ process does not produce a heat affected zone on the cut edge, and the edge only requires a simple deburr to finish the part or blank. Larger parts, up to 4 feet by 8 feet, and smaller parts are cut with equal ease.

Although the AWJ cutting process is cost effective for both medium- and small-lot sizes, the process is more cost effective with small lot sizes because of quick tooling and set-up times. The cost benefit analysis based on Rohr's average lot size produced a net present value of $51,561 on a $298 thousand investment with a two-year, 45 percent internal rate of return.

This project was limited to the application of the AWJ in cutting high strength, flat sheet metal. However, AWJ's ability to cut practically anything without heat, such as laminated and metal matrix composites, presents a bright future for the technology in cutting advanced aerospace materials.

FOR ADDITIONAL INFORMATION: To discuss this effort further, contact: Project Engineer: Brian Wilson, Air Force Manufacturing Technology Program, ATTN: AFWAL/WRDC/MTPM, Wright Patterson AFB, OH 45433-6533; (513)255-5037. Refer to contract: F33615-86-C-5010.

Technology Assessment
U.S. Air Force

Laser-Assisted Thermoplastic Consolidation

The objective of this project is to develop and demonstrate a low cost, laser-assisted thermoplastic consolidation system capable of applying thermoplastic tape on a contoured workpiece. The system will be designed to weld plies of 3-inch wide graphite reinforced thermoplastic tape. The project will result in a consolidation demonstration of a fully consolidated multi-ply contoured laminate. This program takes full advantage of the development achieved during the Manufacturing Science of Complex Shape Thermoplastics contract. The key improvement to be addressed in this program is the simultaneous application of heat pressure in a continuous manner over a complex contour workpiece.

Task I will develop and demonstrate a device that is capable of applying thermoplastic tape on a given contour while applying heat, pressure, and cooling. Task 2 will address the optics to provide active laser nip-heat and preheat components.

The Laser-Assisted Thermoplastic Consolidation program will be performed by the Applied Technology Division of Oak Ridge National Laboratory over a 12-month period. This program is sponsored by the Wright Research and Development Center (WRDC), Manufacturing Technology Directorate.

FOR ADDITIONAL INFORMATION: To discuss this effort further, contact: Project Engineer: Diana M. Carlin, Air Force Manufacturing Technology Program, ATTN: AFWAL/WRDC/MTPN, Wright Patterson AFB, OH 45433-6533; (513)255-7361. Refer to contract: WRDC MIPR No. FY1133-90-05075.

Machining Initiatives For Aerospace Small Subcontractors: Management Planning and Control Systems

Solion Systems has developed a management planning and control system (MPCS) that can be tailored to the specific needs of the machining subcontractor. MPCS supports the information management functions of the small manufacturer; a flexible and tailorable system is necessary since small machining shops vary in their operating philosophy and structure.

The MPCS modular software program is capable of storing all of the information and data required to support a customer quoting and work order control system and a planning/control system including scheduling, capacity planning, inventory control, shop-floor control, performance measurement, and processing planning capabilities. The performance requirements had to meet the following needs of the small manufacturers: ease of use, accuracy, response time, security, flexibility, and general conformance to the way they do business.

A complete system for management planning and control was developed and is available on the commercial market. The software consists of six major modules: quote/order processing, process planning, shop-floor control, resource control, production scheduling, and financial interface. The financial interface module is written to interface with Deltek accounting software, which is available on the commercial market. The software is available for two platforms—Convergent Technologies Mighty Frame with a UNIX operating system and DEC Microvax II with a VMS operating system. Both systems use the database manager called O RALLE. The development effort involved Dravo Automation Sciences, Solion Systems, and four manufacturing companies—Advanced Tool and Die of St. Louis, Missouri; Castle Precision Industries of Van Nuys, California; Meyer Tool of Cincinnati, Ohio; and Seeley Enterprises of Albuquerque, New Mexico. These four companies participated in the analyses and requirements phase of the project and acted as alpha sites for production prototyping. All sites have had versions of the software installed for use in day-to-day operations.

Implementation and use of the MPCS resulted in a 38.5 percent internal rate of return on measured cost items. The intangible benefits included reduced data input time, increased traceability of jobs, and better utilization of resources. For example, in quote/order processing, the MPCS allowed Meyer Tool to reduce the time that it takes to develop a quote by 68.6 percent, thus allowing an increase of almost 300 percent in business volume. Program success has translated into commercial products that have been installed in companies, such as Aerojet and in government facilities, such as the Navy's Lakehurst, New Jersey facility.

FOR ADDITIONAL INFORMATION: To discuss this effort further, contact: Project Engineer: Brian Wilson, Air Force Manufacturing Technology Program, ATTN: AFWAL/WRDC/MTPM, Wright Patterson AFB, OH 45433-6533; (513)255-5037. Refer to contract: F33615-86-C-5010.

Navy Manufacturing Technology

Automated Manufacturing Research Facility

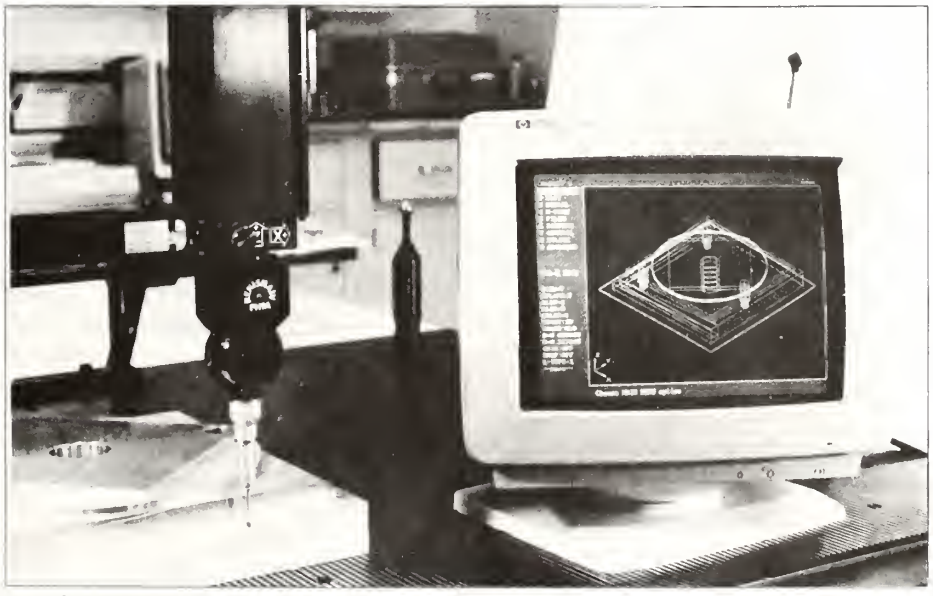
National Institute of Standards & Technology
U.S. Department of Commerce, Gaithersburg, MD 20899

Automated Manufacturing Inspection System

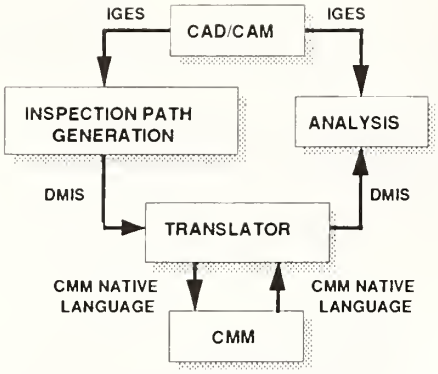
The Quality in Automation (QIA) program presently underway at the National Institute of Standards and Technology (NIST) is developing a quality assurance program that demonstrates "deterministic metrology" in an automated manufacturing environment.

Deterministic metrology allows the control system, in principle, to identify the causes of all errors within a manufacturing process. Process models then allow the system to "explain" the errors and, theoretically, correct them. The system architecture for the program consists of four control loops that are designed to shorten product cycle time and maintain product quality. The goal is to implement a manufacturing system that both monitors significant manufacturing process parameters, and also responds to changes in those parameters.

The metrological anchor of the QIA control architecture is the post-process gauging loop. Here, an automated inspection system is being developed which gathers detailed and accurate information from a machined part. The system is designed to reduce inspection times while increasing reliability and



The CMM uses a touch probe to measure a test part using an inspection program automatically generated by CAD/CAM software



Automated Inspection System

accuracy (as well as ease) of measurement.

The automated inspection system is a stand-alone, P.C. based system that can be integrated into a manufacturing process at a reasonably low cost and without the need for much knowledge of complex computer systems. The entire inspection process from part program generation to inspection result analysis, is controlled from one enhanced 386-class P.C.

The inspection process begins with a CAD representation of the manufactured part. This three-dimensional, wire-frame model (which can also be used to produce NC tool paths) is then translated into an Initial Graphics Exchange Specification (IGES) file, which is sent to a coordinate measuring machine (CMM) programming software package. The CMM programming package uses the IGES file to produce a CMM inspection program for the part. The inspection program is created graphically on the computer screen using input from a mouse device, and a computer simulation of the CMM inspection process can then be viewed.

The program is in the format of the Dimensional Measurement Interface Specification (DMIS) standard, which is designed to be a universal language to interface between CAD systems and inspection hardware. This DMIS file is then translated into the native language of the CMM. The CMM, which operates under direct computer control, then automatically performs the part inspection and produces inspection results in the form of a DMIS output file. This DMIS output file is then sent into a metrology-based analysis software product, which can perform a variety of analyses on the results, including both quantitatively and graphically comparing the inspection results with the part's original design.

The results of the automated inspection process are integrated with the data collected during the other three control loops of the QIA system to improve the existing manufacturing process, as well as to detect trends in manufacturing processes to be used to improve the quality of future production runs.

The majority of the hardware and software in the post-process gauging loop is being used at NIST as part of research associate (RA) agreements with private industry. All of the products are, or soon will be, commercially available and are on loan to NIST free of charge from the manufacturers. The manufacturers involved with these RA agreements are Sheffield Measurement, Renishaw Inc., CMX Systems Inc., CADKEY Inc., Automation Software, and ICAMP Inc.

FOR ADDITIONAL INFORMATION: To discuss this effort further, contact: David C. Stieren, Bldg. 220, Room A107, AMRF Project National Institute of Standards & Technology, Gaithersburg, MD 20899; Telephone: (301) 975-3197.

Navy Manufacturing Technology

Automated Manufacturing Research Facility

National Institute of Standards & Technology
U.S. Department of Commerce, Gaithersburg, MD 20899

Tool Management for the Rock Island Arsenal

Engineers from the National Institute of Standards and Technology (NIST) and the U.S. Army Rock Island Arsenal (RIA) have completed the requirements analysis and architecture design for a tool management system.

Open architecture concepts used in the design of the RIA system were developed by NIST staff at the Automated Manufacturing Research Facility (AMRF). The tool management architecture is intended to serve as a reference model, defining the major subsystems and the interfaces that exist between them. It could serve as a basis for planning the future integration of tool management functions into other DOD manufacturing facilities.

Tool management is an essential part of a manufacturing system's operation. Required functions are tool preparation (design, fabrication, assembly), tool crib management, tool planning, reassignment of tools, and efficient use of tool life. The failure of a manufacturing system to perform these functions properly, i.e., to get the right machine at the right time, can often bring production processes to a halt.

The systems that perform these functions must be capable of interacting with each other, with other systems, and with people performing manual activities. Current commercial "turnkey" products have limited capabilities and are basically stand-alone systems. They are difficult to integrate into a larger factory information structure.

Because industry has only recently begun to look closely at integrated tool management, little information about it is publicly available. No commercial systems exist which perform all of the functions required from automated manufacturing.

The next step of the NIST/RIA effort will be to:

- develop computer simulations of the proposed system.
- develop detailed system design specifications.

When this specification phase is over, the technical and economic feasibility of the proposed system will be assessed.

FOR ADDITIONAL INFORMATION: For further information, contact: Simon Frechette, Building 220, Room A127, AMRF Project, National Institute of Standards & Technology, Gaithersburg, MD 20899; (301)975-3335.

NASA Tech Brief
National Aeronautics and Space Administration
Marshall Space Flight Center, Alabama

Arc Reflector for Welding Ducts

The reflector is improved for use on round ducts.

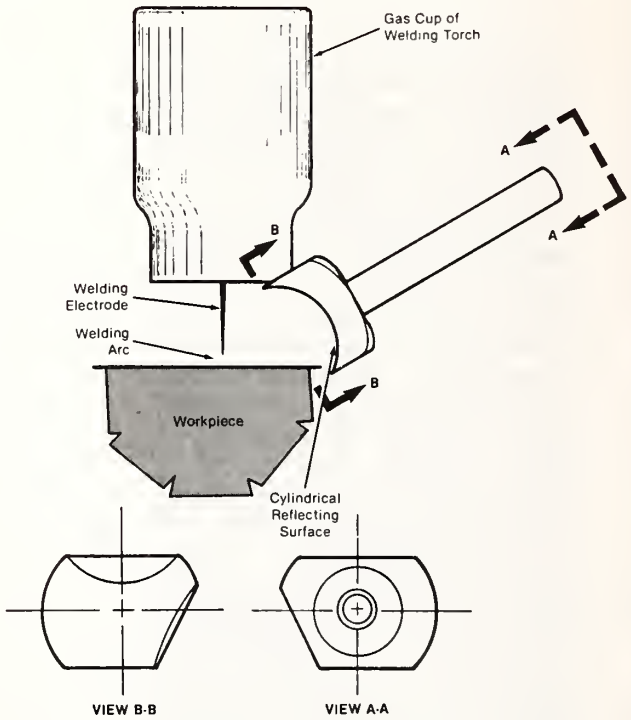
An arc-light reflector for a through-the-torch welding vision system is designed expressly for use in welding ducts of small diameter. The reflector has a cylindrical surface instead of the conical surface used for flat-plate welds.

The reflector directs light from the welding arc to the workpiece so that it presents a bright image for the vision system, by means of which the weld is viewed along the axis of the welding torch. The image could be used, for example, to control a welding robot. The cylindrical contour of the reflector distributes the light more evenly over the viewed surface than a conical reflector would.

The reflecting surface is blasted with aluminum oxide to obtain diffuse reflection. The position and orientation of the reflector can be adjusted by a small two-axis manipulator.

The reflector is no wider than the gas cup on the welding torch. The reflector is not attached to the cup, which, therefore, can be removed and replaced with ease.

This work was done by Jeffrey L. Gilbert of Rockwell International Corp. for **Marshall Space Flight Center**. *No further documentation is available.*
MFS-29640/TN



The Cylindrical Reflector is positioned to reflect light diffusely from the welding arc onto the nearby surface of the workpiece for most advantageous viewing along the axis of the welding torch.

FOR ADDITIONAL INFORMATION: *Contact: Director, Technology Transfer Division, P.O. Box 8757, BWI Airport, MD 21240; (301) 621-0100 Ext. 241*
REFER TO THE NUMBER LISTED AT THE END OF THIS ARTICLE

NASA Tech Brief
National Aeronautics and Space Administration
Marshall Space Flight Center, Alabama

Licensing Opportunity

Compact Pinch Welder

An easy-to-use gun boosts productivity.

A compact resistance-welding pinch gun lets one operator do jobs that formerly needed two workers. The gun is light in weight and produces repeatable, high-quality weld joints.

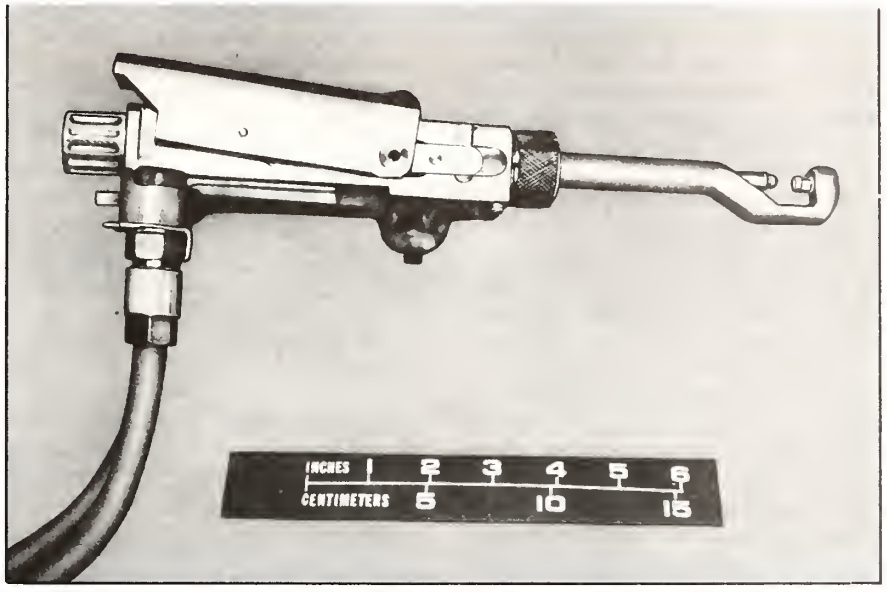
The gun has a pair of electrodes that pinch the workpiece between them when the operator presses a lever (see figure). One operator can position the electrodes in precisely opposing positions; it is not necessary to have an operator for each electrode. Pressure from the preset spring loaded plunger provides the welding force.

When the electrodes are in welding position and the welding force is applied, the operator pushes a button on the handle of the gun to turn on the welding current. A spot weld is quickly made, and the operator can move to the next weld position.

The gun has a rotating electrode head with narrow jaws that makes it easy for the operator to reach into limited-access areas and maneuver the gun. It can be used for alternating-current or direct-current welding.

This work was done by Thomas F. Starck and Andrew D. Brennan of Rockwell International Corp. for **Marshall Space Flight Center**. *No further documentation is available.*

Inquiries concerning rights for the commercial use of this invention should be addressed to the Patent Counsel, Marshall Space Flight Center. Refer to MFS-29612/TN.



The **Welding-Electrode Head** (right) rotates for easy positioning. The lever at top of the handle activates a spring to pinch the electrodes together at a preset welding force. The button at the bottom of the handle activates the welding current. Cables at left supply electrical power.

George C. Marshall Space Flight Center
Technology Utilization Officer: Ismail Akbay
Code AT01
Marshall Space Flight Center,
AL 35812
(205) 544-2223

Patent Counsel: Leon D. Wofford, Jr.
Mail Code CC01
Marshall Space Flight Center,
AL 35812
(205) 544-0024

FOR ADDITIONAL INFORMATION: *Contact: Director, Technology Transfer Division, P.O. Box 8757, BWI Airport, MD 21240; (301) 621-0100 Ext. 241*
REFER TO THE NUMBER LISTED AT THE END OF THIS ARTICLE

NASA Tech Brief
National Aeronautics and Space Administration
NASA's Jet Propulsion Laboratory, Pasadena, California

Licensing Opportunity

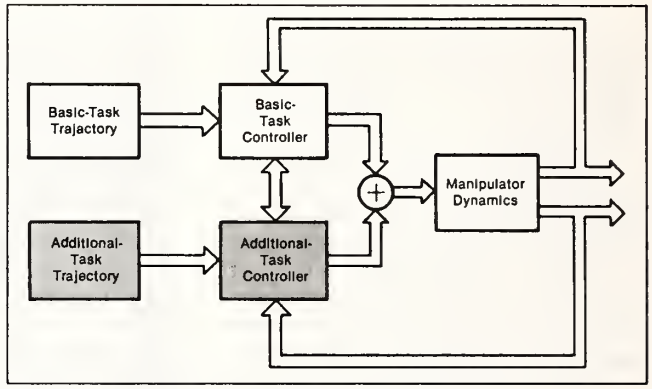
Increasing the Dexterity of Redundant Robots

Redundant coordinates are used to define additional tasks.

Configuration control is emerging as an effective way to control the motions of a robot that has more degrees of freedom than are necessary to define the trajectory of the end effector and/or of the object to be manipulated. The extra or redundant degrees of freedom can be used to give the robot humanlike dexterity and versatility.

In configuration control, the configuration of the robot is represented mathematically by a set of configuration variables, which is a generalized coordinate vector that is more relevant to the overall task than is the vector of joint coordinates that appears in conventional approaches to control. The generalized coordinate vector consists of the coordinates of the end effector in task space, plus a number of kinematic functions that involve the redundant degrees of freedom. The basic task of the control system is to make the coordinates of the end effector follow the desired trajectory. The kinematic functions can be selected to define an additional task — for example, the avoidance of obstacles or kinematic optimization to enhance manipulability. In effect, the additional task defines the trajectory in the redundant degrees of freedom (see figure).

The configuration variables can be used in an adaptive control scheme, which does not require knowledge of the complicated mathematical model of the dynamics of the robot or the parameters of the object to be manipulated. The configuration-control method can be implemented in either a centralized or a decentralized control system. Because configuration control is computationally very fast, it is suitable for the development of algorithms for the real-time control of robots.



The **Configuration Controller** acts, in effect, as a basic-task controller (which makes the end effector move along the desired trajectory) plus an additional-task controller (which performs an additional task—for example, kinematic optimization).

This work was done by Homayoun Seraji of Caltech for **NASA's Jet Propulsion Laboratory**.

Inquiries concerning rights for the commercial use of this invention should be addressed to the Patent Counsel, NASA Resident Office-JPL. Refer to NPO-17801/TN.

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REFER TO THE NUMBER LISTED AT THE END OF THIS ARTICLE

NASA Tech Brief
National Aeronautics and Space Administration
Langley Research Center, Hampton, Virginia

Licensing Opportunity

Integrated Process for Insertion and Beatup of Fill Yarns

This process works with angle-ply weaves.

An integrated apparatus and process have been devised for the insertion and beatup of fill yarns during the weaving of fabrics containing bias-oriented yarns. This new technology supplants the old shuttle method and the modern water-jet method of insertion and the conventional reed method of beatup. The integrated apparatus and process are intended for use in the angle-ply or bias-direction weaving process described in the preceding article because the methods for inclusion of the bias-oriented yarns typically result in sheds that are incompatible with conventional reed beat-up techniques.

The major components of the apparatus are the rapier, the fill-yarn channel, the flexible and inflatable boot that fits in the fill-yarn channel, the boot guides, and the hydraulic actuators that push the rapier into the fell of the fabric (see Figure 1). A clip holds one end of the fill yarn at one end of the rapier while the fill yarn is inserted in the channel. The fill yarn is inserted under tension to keep it straight. The flexible boot is guided back into the channel by use of a guide when the rapier is extended and retracted. The insertion of the fill yarn also assists in the reinsertion of the boot into the channel.

As the rapier is extended across the fabric, the fill yarn is inserted in the channel. When the rapier is fully extended, the rapier receiver catches and holds the end of the rapier. Hydraulic actuators are energized, and the rapier is pushed into the fell of the fabric, as depicted in Figure 2. While the rapier is in the fell, the boot is inflated, pushing the fill yarn out of the channel.

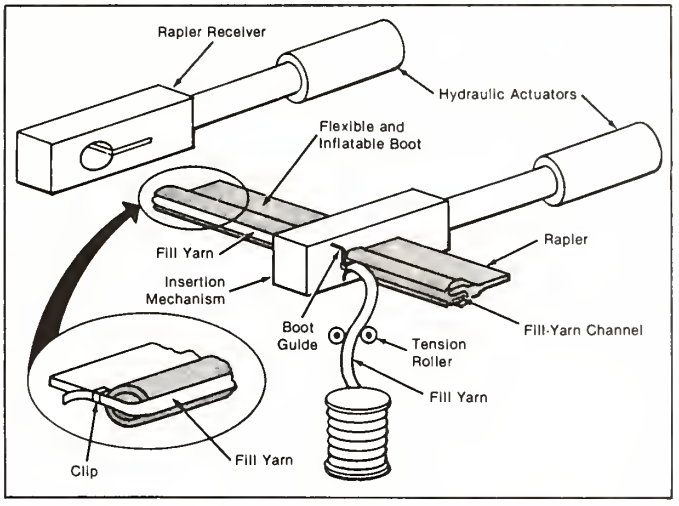

Figure 1. The **Fill Yarn Is Inserted in the Channel** by moving the rapier past the insertion mechanism.

The hydraulic actuators are then deenergized and the rapier is pulled out of the fell. The rapier is retracted out of the shed, and the shed is closed. This process is repeated until all of the fill yarns are inserted, and the fabric is advanced.

This work was done by Gary L. Farley of **Langley Research Center.**

This invention is owned by NASA, and a patent application has been filed. Inquiries concerning nonexclusive or exclusive license for its commercial development should be addressed to the Patent Counsel, Langley Research Center. Refer to LAR-14046/TN.

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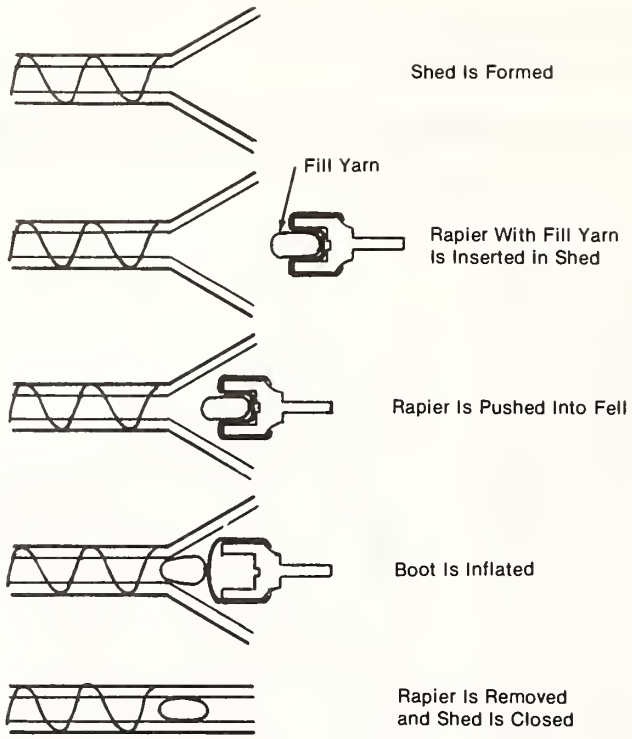


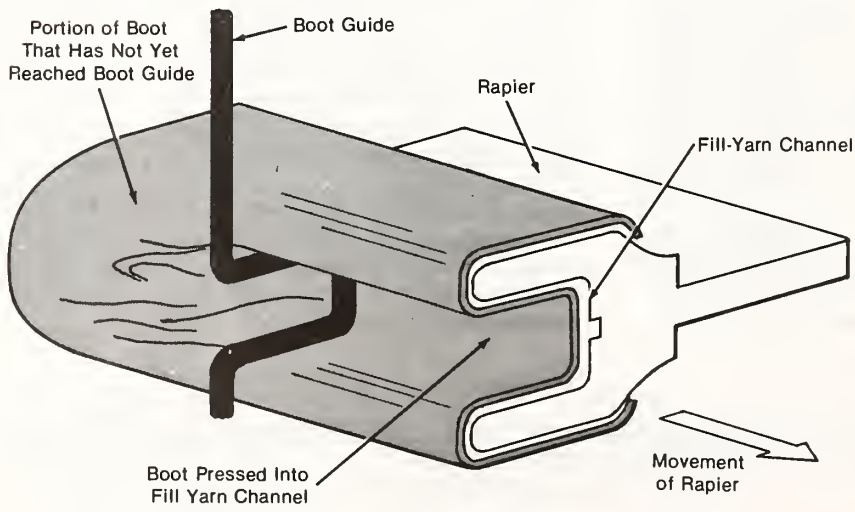


Figure 2. The **Fill Yarn Is Inserted and Beat Up** in this sequence of steps. After insertion and beatup, the rapier is moved past the insertion mechanism in the opposite direction, and the boot guide pushes the boot back into the fill-yarn channel.

NASA Tech Brief
National Aeronautics and Space Administration
NASA's Jet Propulsion Laboratory, Pasadena, California

Licensing Opportunity

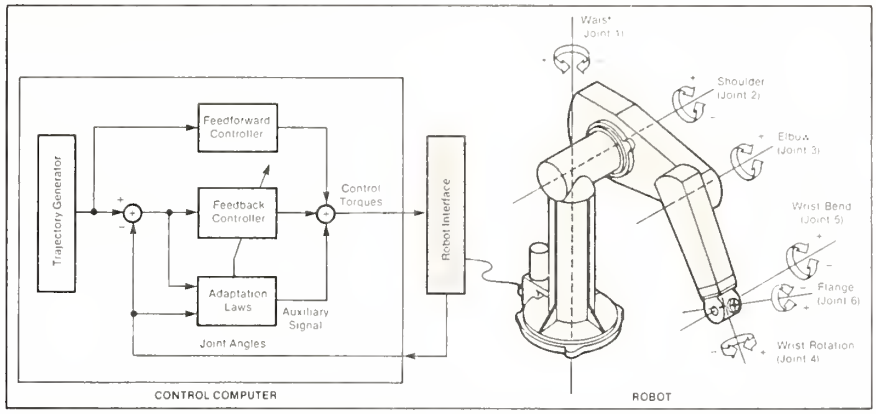
Robust, High-Performance Control for Robotic Manipulators

Model-based and performance-based control techniques are combined.

An improved control scheme for robotic manipulators results from an alternative approach to the use of both model-based and performance-based control techniques. This is a robust, high-performance adaptive control scheme that combines the advantages and overcomes the disadvantages of both types of techniques.

Model-based control techniques like the Computed-Torque method are based on the cancellation, by the controller, of nonlinear terms in the mathematical model of the dynamics of the manipulator. Such techniques require that the model be accurate, that all the parameters of the model be known accurately, and that the model be computed in real time at the servo control sampling rate. These requirements are often not met in practice. Performance-based (adaptive) techniques like the direct-adaptive-control method attempt to overcome the failure to satisfy these requirements by adjustment of the controller gains in real time on the basis of the tracking performance of the manipulator. This eliminates the need for the model and for the computation of its parameters. Thus, a fast adaptation can be achieved. However, adaptive controllers do not take advantage of any known part of the dynamics. Furthermore, rates of adaptation that are set high enough for rapid response to variations in the manipulator dynamics or payload can cause instabilities through the excitation of unmodeled dynamics.

The new control system includes a feedforward controller and a separate feedback controller. The feedforward controller is model-based and contains any known part of the dynamics of the manipulator that can be used to produce a nominal control signal. The feedback controller is performance-based; it compensates for any unknown dynamics and uncertainties or variations in the parameters of the manipulator and/or the payload. The feedback controller is a simple adaptive proportional/integral/derivative controller that generates an adaptive control signal to complement the nominal feedforward signal. The feedback laws are simple, enabling fast implementation of the servo control loop. To counteract potential instabilities and assure robustness in the presence of unmodeled dynamics and disturbances, decay terms are included in the integral adaptation laws.



An **Experimental Control System** tracked the commanded trajectory closely, demonstrating the soundness of the new approach to the combination of model-based and performance-based control.

A version of the new control scheme was tested by using it in the control computer of a commercial robot (see figure). The robot was found to track the commanded trajectory closely, even when the mathematical model of the dynamics was not used and the feedforward controller was eliminated. The results also showed that the control scheme is not sensitive to the configuration of the robot arm, torque disturbances, or the desired trajectory.

This work was done by Homayoun Seraji of Caltech for **NASA's Jet Propulsion Laboratory.**

This invention is owned by NASA, and a patent application has been filed. Inquiries concerning nonexclusive or exclusive license for its commercial development should be addressed to the Patent Counsel, NASA's Resident Office-JPL. Refer to NPO-17785/TN.

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REFER TO THE NUMBER LISTED AT THE END OF THIS ARTICLE

NASA Tech Brief
National Aeronautics and Space Administration
Marshall Space Flight Center, Alabama

Ultrasonic Abrasive Removal of EDM Recast

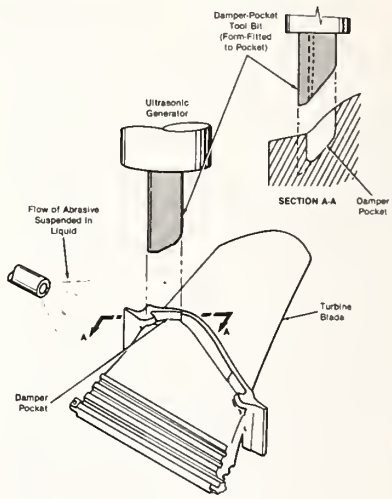
A form-fitted tool is vibrated in the presence of abrasive material.

An ultrasonic abrasive process removes the layer of recast material that is generated during the electrical-discharge machining (EDM) of a damper pocket on a turbine blade. Heretofore, recast material has been removed by blasting with abrasive powder.

The removal of material is controlled precisely by a tool bit that is form-fitted to the damper pocket. Abrasive medium is made to flow across the turbine blade while the tool is vibrated ultrasonically in the damper pocket (see figure). The vibrations of the tool bit direct the abrasive material to the only areas from which it is desired to remove material — the walls of the damper pocket.

The amount of material removed can be controlled precisely. This amount is determined mainly by the duration of the ultrasound. Material is removed to an equal depth on all surfaces in proximity to the tool bit.

This work was done by Johnny L. Mandel and Marlowe S. Jacobson of Rockwell International Corp. for **Marshall Space Flight Center**. *No further documentation is available.*
MFS-29545/TN



The **Form-fitted Tool** is vibrated ultrasonically in the damper pocket from which material is to be removed. The vibrations activate the abrasive in the pocket.

FOR ADDITIONAL INFORMATION: *Contact: Director, Technology Transfer Division, P.O. Box 8757, BWI Airport, MD 21240; (301) 621-0100 Ext. 241*
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Department of Energy

Technology Application

Lawrence Berkeley Laboratory

Fault Location System

Researchers at Lawrence Berkeley Laboratory (LBL) have built a software system that locates faults in complex machinery. The system is called FindIt. It detects failures by monitoring the system's output data streams. Upon operator request, FindIt then uses a high performance database to instantly trace the failure back to the components most likely to have caused the failure. The software is based on well established technologies including statistical testing, graph theory, set theory, data set organization, and a "software bus."

Successful operation of a manufacturing plant or a chemical production plant requires the reliable operation of hundreds of thousands, even millions, of complex components. Monitoring each individual component is usually too costly to consider. Therefore, the failure of a single component may be difficult to trace, especially since the effect of the failure may not be detected at a point that is near the failed component.

The inability to quickly diagnose the causes of failure in a complex manufacturing process can result in costly downtime. Current process monitoring systems are designed to detect the occurrence of a problem, but few are capable of identifying failed components when the possibilities number more than a few thousand.

The ability to quickly find and diagnose a complex system error translates to large savings in process control and factory automation - reduced downtime, improved quality control. FindIt also builds confidence. There is never a doubt about the system, because the software provides a dynamic overview of the entire process.

As a proving ground for this technology, FindIt was applied to a particle detector (the HISS Time of Flight Wall) that has several thousand "breakable" components and over 700 output channels.

The project achieved significant breakthroughs on two levels: At the end-user level, it produced a system that can monitor a variety of running equipment (not just detectors) and identify malfunctioning components in real time. At the software engineering level, it produced a collection of reusable software components that can be applied to general scientific computing problems. This makes the system especially easy to adapt to new environments.

Potential industrial applications for LBL's FindIt system include chemical process control, testing of electronic circuit boards, factory automation, and software debugging.

Beyond its ability to diagnose running equipment, the fault location system has the potential to be used to help produce more reliable equipment designs. The fault identification mechanism can readily be reconfigured to predict the ease with which a proposed design can be diagnosed.

For the software itself, the bus approach offers industry a way to combine software products from different vendors without compromising the competitive advantage of either party. It is particularly easy to adapt the system to new applications. The fault location system is scalable to applications having millions of components.

FOR ADDITIONAL INFORMATION: FindIt is available for licensing from Lawrence Berkeley Laboratory. For further information contact Mark Owens at (415)486-6463.

Holographic Wafer Inspection

The functional density and operational speed characteristics of integrated circuits have led to the development of advanced wafer-processing equipment. The wafers have increased in size, and the devices on the wafers have become more complex with smaller feature sizes. Because of their small-size features and their susceptibility to damage from probe contacts, the devices require noncontact inspection techniques. Holographic inspection techniques offer a noncontact and nondestructive system that is fast and highlights defects over a major portion of the wafer. Rather than die-by-die inspection, partial or whole wafer inspection, using holographic methods, has the potential of drastically reducing the time associated with wafer inspection and affords real time, inline process quality. Furthermore, if whole wafer inspection is conducted during processing, processing problems can be identified early for increased yield.

The program is divided into two separate phases. Phase I is the assessment of holographic technology as it pertains to inspection of wafers used in manufacturing integrated circuits. Phase II is the optimization of holographic inspection—that is, the application of the knowledge acquired in phase I to the in-process inspection of actual product wafers during manufacturing.

Phase I, Assessment of Holographic Technology took place at National's Fairchild Research Center (FRC) in Santa Clara, California. Phase I showed that the holographic technology has definite value for wafer inspection and defect reduction in manufacturing silicon integrated circuits. The three dimensional quality of holographic inspection facilitates detection of defects not found using optical inspection methods.

Whole wafer inspection allows the process engineer to see defect patterns, which is not possible using die-by-die inspection techniques. Defect patterns can indicate specific process problems that need correction. Cycle time is minimized by eliminating time spent to "work around" wafers which have gone through problem processes.

The phase II plan for optimization is expected to be complete in February 1991. Results so far indicate that optimal use of such a wafer inspection tool is for process control, which is used for observing whole wafer defect patterns.

The contractor, National Semiconductor, received and installed an Insystems 8600 holographic inspection system owned by the SEMATECH consortium. This system has been returned to SEMATECH for phase I work. National Semiconductor has subsequently purchased their own Insystem 8600.

FOR ADDITIONAL INFORMATION: To discuss this effort further, contact: Project Engineer: Mary Kinsella, Air Force Manufacturing Technology Program, ATTN: AFWAL/WRDC/MTEM, Wright Patterson AFB, OH 45433-6533; (513)255-2142. Refer to contract: F33615-88-C-5442.

NASA Tech Brief
National Aeronautics and Space Administration
Marshall Space Flight Center, Alabama

Enhancement of Penetrant-Inspection Images

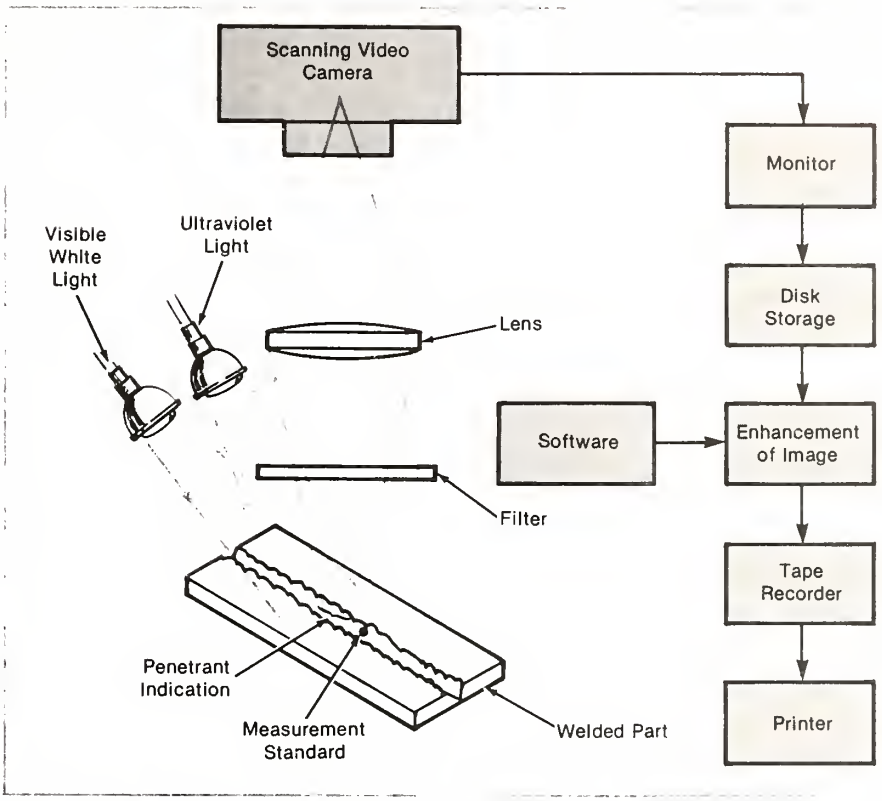
Software makes flaws more apparent and creates a data base.

A proposed computerized video system would process images of fluorescent dyes absorbed in flaws in welds. The system would enhance images of cracks and voids so that they can be evaluated by human inspectors without the subjectivity that affects ordinary inspections. The system would also provide quantitative measurements that could be compiled in a data base for future use.

The system (see figure) would freeze images on the video screen so that they could be stored, magnified, and documented by photographs. It could remove unwanted background images and would exaggerate the differences between light and dark areas. It could convert positive images to negative ones to make flaws more obvious.

The system would be able to delineate "windows" — sections of the image that could be enhanced, magnified, or stored. It could change the shape, size, and position of a window as directed by the operator. It could "cut and paste" — that is, isolate sections of images and reposition them side-by-side for comparison.

It could sharpen the edges of fine features of an image. With its picture elements calibrated to a standard, the system could measure the sizes of flaws. It could identify flaws by type by comparing them with data on flaws stored in memory. It could discern true flaws from harmless features, thereby eliminating unnecessary rework.



A **Video Camera**, held by an operator or by a remote manipulator, would view a weld illuminated by visible white and ultraviolet light. Images of penetrating dye in cracks and voids in the weld joint would appear on a video monitor. The fluorescent features would also be enhanced by software to facilitate the identification of true flaws and record important data.

This work was done by Rhonda C. Wilson of Rockwell International Corp. for **Marshall Space Flight Center.** *MFS-29496/TN*

FOR ADDITIONAL INFORMATION: *Contact: Director, Technology Transfer Division, P.O. Box 8757, BWI Airport, MD 21240; (301) 621-0100 Ext. 241*
REFER TO THE NUMBER LISTED AT THE END OF THIS ARTICLE

Materials

0190 Clothing Insultating Material is More Efficient

0191 New Precursor Shortcuts the Process for Making Silicon-Carbide Ceramic Fibers

0192 Guidelines Issued for Pressure Vessel Safety Assessment

0193 New Glass Density Standards Available for Industry

0194 PC Database To Speed Use of Advanced Ceramics

0195 Braided Composite Threaded Fasteners—Stronger fasteners would be made with less waste. (Licensing Opportunity)

0196 Angle-Ply Weaving—Fibers can be woven along the bias. (Licensing Opportunity)

Software

0197 Calculating masses, Densities, and Compositions of Alloys—Three simple computer programs perform routine metallurgical calculations.

0198 Computing Blood Flows—Methods developed for aerospace could be applied to the mechanics of biofluids.

0199 Effects of Rapid Crushing on Composites—Effects of crushing speeds on energy-absorbing capabilities of composites are studied experimentally.

0200 Treating Nickel Alloy for Sonic Quality—Bars are processed to enable acoustic monitoring of stress. (Licensing Opportunity)

Testing & Instrumentation

0201 Technique Boosts Hypervelocity Materials Impact Testing

0202 Advanced Field NDE System Producibilty, Advanced Real-Time Inspection System

Other Items of Interest

0177 Laser-Assisted Thermoplastic Consolidation

0184 Integrated Process for Insertion and Beatup of Fill Yarns—This process works with angle-ply weaves. (Licensing Opportunity)

U.S. Army Research

U.S. Army Natick RD&E Center, Natick, MA 01760

Clothing Insultating Material Is More Efficient

A Federal Laboratory Consortium Excellence in Technology Transfer Award was awarded to two Natick materials scientists, Deidre Rapacz and Stephen Fossey, for the development of a synthetic batting, PRIMALOFT™. PRIMALOFT is a synthetic that contains fine microfilaments that trap more radiant heat than other synthetic insulators and reduce convective heat loss. Not only is this development beneficial to DoD, but it has already been transferred to the commercial marketplace. It is featured by the clothier L.L. Bean in their winter jacket line and has also been selected by an international team of American, Soviet and Chinese climbers on their landmark expedition to the summit of Mount Everest.

For Additional Information:

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(508) 651-5296

Ames Laboratory

New Precursor Shortcuts the Process for Making Silicon-Carbide Ceramic Fibers

Ames Laboratory chemists have developed a new process for making silicon-carbide fibers from polymers. This process may provide industry with an alternative to importing these materials from Japan, at the cost of $300 to $500 per pound.

Although silicon-carbide can be easily and cheaply made from sand and carbon, the only way to make silicon-carbide fibers is to make them from polymers. Until now, only the Japanese have been able to make commercial-grade continuous silicon-carbide fibers from polymers, namely, polysilane. Efforts by U.S.industry to reproduce the Japanese process have failed, mainly due to the complexity of transforming polysilane into an intermediate form and then into ceramic fiber. Another problem has been knowing how to keep the main chain of the polymer intact, while heating or subjecting it to other treatment to get rid of unwanted "side groups" and convert it to ceramic.

The Ames chemists started with the same monomer materials as the Japanese, but instead of reacting the monomers with sodium, they reacted them with dilithium acetylene (LiC=LiC). The yield of the resulting polymer was extremely good, about 90 percent. The polymer could be melted and pulled into a fiber that was extremely fine, on the order of 5 to 20 micrometers. But most importantly, the Ames researchers found they could take this polymer fiber and heat it directly to high temperatures to make ceramic fiber. This direct step was a significant improvement over the Japanese method, where the polymer needed to go through a significant improvement over the Japanese method, where the polymer needed to go through a polycarbosilane form before ceramic could be made. The Ames process solved the problem of keeping the main polymer chain intact and also avoided the complex intermediate step of the Japanese method. The only thing researchers needed to do to prepare the Ames polymer fiber for high temperature heating was expose it to ultraviolet light to form a protective layer that would keep the fibers together throughout heating.

Ames chemists collaborated with staff at Iowa State University's materials science and engineering department to develop the fiber processing techniques. The Iowa State University Center for Advanced Technology Development is funding additional studies and testing to determine optimal processing conditions, a major factor in large scale manufacture.

The demand for the fibers comes from the fact that they can be mixed with ceramic powder to form lightweight composite materials with superior heat resistance and strength. They are also resistant to chemical breakdown. These properties give them a competitive advantage over existing metals and ceramics. Principally, they could displace materials such as steel and aluminum in many industrial applications. Currently, the market demand for composite materials is around $100 million a year. Experts predict that figure will reach $800 million by the year 2000.

Literature: T. J. Barton, S. Ijadi-Maghsoodi, Y. I. Pang, "Part A, Polymer Chemistry, *Journal of Polymer Science*, Vol. 28, p. 955, 1990.

Patent/License Status: U.S. Patent No. 4,940,767.
Potential Applications/Spinoffs: Aerospace, automobile, medical and sports equipment, ceramic reinforcement furnace curtains, wire and cable insulators, heat resistant clothing.

FOR ADDITIONAL INFORMATION: Contact Daniel E. Williams, Office of Research and Technology Application, Ames Laboratory, 199 Office and Laboratory, Iowa State University, Ames, IA 50011; (515)294-2635.

NIST Technology Update

National Institute of Standards & Technology
U.S. Department of Commerce, Gaithersburg, MD 20899

Guidelines Issued for Pressure Vessel Safety Assessment

Deterioration of certain kinds of pressure and storage vessels in the United States could result in the loss of dozens of lives and millions of dollars. A NIST study, sponsored by the Occupational Safety and Health Administration, gives an overview of stationary, unfired carbon steel and low-alloy steel pressure vessels for liquids and gases, and low-pressure storage tanks used at temperatures between -75 and 315 degrees C (-100 to 600 degrees F). These vessels are used in the process, pulp and paper, petroleum refining, and petroleum chemical industries, and for water treatment systems for boilers and steam generators. *Guidelines for Pressure Vessel Safety Assessment* (NIST SP 780) describes pertinent sections of ASME and API codes and standards governing vessel construction, testing, and inspection; causes of failure; and nondestructive inspection standards, practices, and methods. Data and information needed to assess the safety of these vessels and tanks are also given.

FOR ADDITIONAL INFORMATION: A copy of the report is available from NTIS, Springfield, VA 22161; (703)487-4600.

NTIS order number: PB90-219619NAC
Price code: A05

NIST Technology Update

National Institute of Standards & Technology

U.S. Department of Commerce, Gaithersburg, MD 20899

New Glass Density Standards Available for Industry

NIST has developed four new standard reference materials (SRMs) for the producers of flat and container glass products. The SRMs are quality control standards for calibrating densitometers and other instruments used to measure the density of solids and liquid materials. Each of the SRMs has a certified density value determined by hydrostatic weighing. SRM 1825, Fused Silica Density Standard; SRM 1826, Soda-Lime Glass Density Standard; and SRM 1827, Lead Silica Glass Density Standard are available for $133 each. SRM 1919, Lead Silica Glass Density Standard, is the same material as SRM 1827 but each unit is individually certified to the sixth decimal place. It is priced at $168.

FOR ADDITIONAL INFORMATION: The new glass density standards are available from the Standard Reference Materials Program, Rm. 204, Bldg. 202, NIST, Gaithersburg, Md. 20899; 301/975-6776, fax: 301/948-3730.

NIST Technology Update

National Institute of Standards & Technology

U.S. Department of Commerce, Gaithersburg, MD 20899

PC Database To Speed Use of Advanced Ceramics

A new structural ceramics database (SCD) for personal computers (PCs) is designed to speed the application of high-temperature advanced ceramic materials from the laboratory to the marketplace. The database was developed by NIST materials scientists, with industry support from the Gas Research Institute through the Center for Advanced Materials at the Pennsylvania State University. SCD provides design engineers with rapid access to important information on the thermal and mechanical properties of silicon carbide and silicon nitride monolithic materials. These materials are primary candidates for the manufacture of heat exchangers, ceramic engine components, sensors, and cutting tools because of their high strength and dimensional stability, chemical inertness, and wear resistance.

FOR ADDITIONAL INFORMATION: NIST Structural Ceramics Database (SCD), Standard Reference Database 30, is available for $495. To order PC Version 1.0, contact the Standard Reference Data Program, A320 Physics Bldg., NIST Gaithersburg, MD 20899; 301/975-2208, fax: 301/975-2183.

NASA Tech Brief
National Aeronautics and Space Administration
Langley Research Center, Hampton, Virginia

Licensing Opportunity

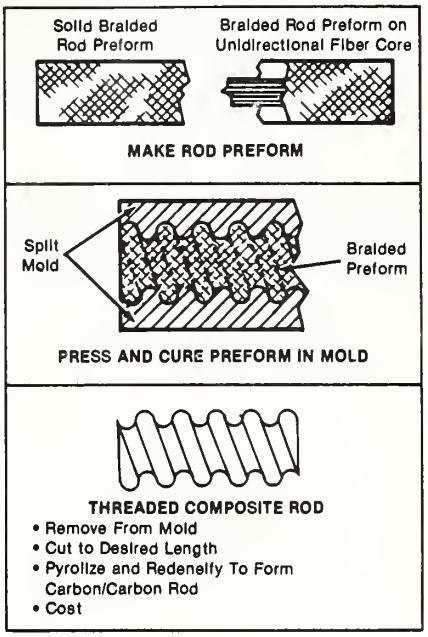
Braided Composite Threaded Fasteners

Stronger fasteners would be made with less waste.

Fasteners of carbon/carbon or other fiber/matrix composite materials could be made by a braiding-and-molding process. These fasteners are intended for use with ceramic and composite-material structural parts at temperatures $\gtrsim$ 2,500 °F ($\gtrsim$ 1,400 °C), at which metal fasteners cannot be used.

Coated carbon/carbon fasteners for use at temperatures in excess of 3,000 °F (~1,600 °C) have been made from three-dimensional woven billets that were processed into carbon/carbon material, machined to the required sizes and shapes, and then coated for protection against oxidation. Weaving and processing are expensive and difficult. Machining is expensive, generates considerable waste, and weakens the fasteners by damaging the fibers. In constrast, the proposed braiding-and-molding process would cost less, produce stronger fasteners by avoiding breakage of fibers, and be adaptable to mass production.

The figure illustrates the fabrication of a threaded rod by the proposed method. A two- or three-dimensional braiding technique would be used to make a fiber preform, which would then be impregnated with matrix material. The impregnated preform would be pressed between the halves of a split mold, the inner surface of which would have the desired thread pattern. After curing under pressure, the threaded rod would be removed from the mold, cut to desired lengths, processed to final state, and coated for protection against oxidation at high temperatures.


Solid Braided Rod Preform
Braided Rod Preform on Unidirectional Fiber Core
MAKE ROD PREFORM
Split Mold
Braided Preform
PRESS AND CURE PREFORM IN MOLD
THREADED COMPOSITE ROD
• Remove From Mold
• Cut to Desired Length
• Pyrolize and Redensify To Form Carbon/Carbon Rod
• Cost

A **Preform of Braided Fibers** impregnated with matrix material would be pressed and cured in an internally threaded, split mold to make an externally threaded rod.

Many variations of the basic concept are possiible. The braiding could be performed with fibers precoated with matrix material, eliminating the impregnation step. The preform could be made by braiding onto a previously formed unidirectional fiber core, which would provide increased tensile stiffness and strength. Plugs could be inserted in preforms and later removed to form screwdriver slots, sockets, keyways, and the like. Other core materials could be used. Other parts like nuts, hubs, or hollow shafts with or without splines could be made by use of various combinations of internal and split external molds. Even in cases in which threads could not be completely molded onto braided preforms, it is expected that threads superior to those machined onto woven billets could be machined onto the braided preforms, and at a lower cost.

This work was done by James Wayne Sawyer of **Langley Research Center**. *No further documentation is available.*

This invention is owned by NASA, and a patent application has been filed. Inquiries concerning nonexclusive or exclusive license for its commercial development should be addressed to the Patent Counsel, Langley Research Center. Refer to LAR-14062/TN.

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REFER TO THE NUMBER LISTED AT THE END OF THIS ARTICLE

NASA Tech Brief
National Aeronautics and Space Administration
Langley Research Center, Hampton, Virginia

Licensing Opportunity

Angle-Ply Weaving

Fibers can be woven along the bias.

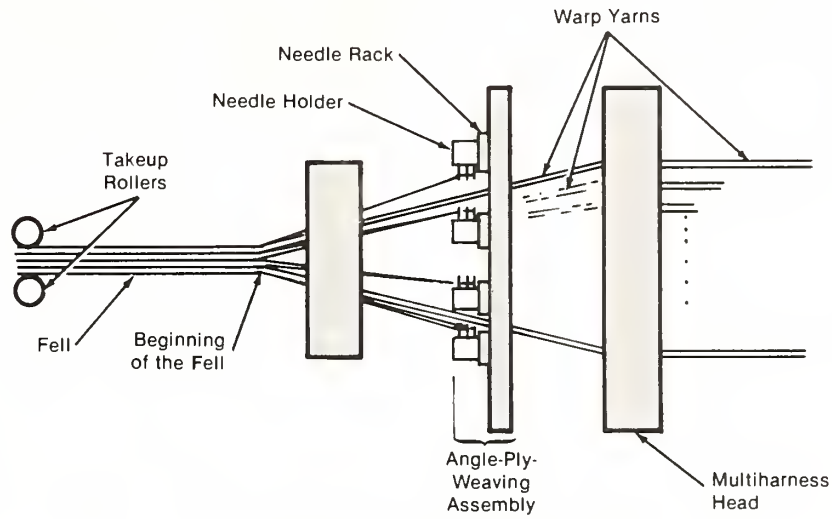
Bias-direction or angle-ply weaving is a proposed new process for weaving fibers along the bias in a conventional planar fabric or in a complicated three-dimensional multilayer fabric preform of a fiber-reinforced composite structure. Fibers woven along the bias would increase the shear stiffness and shear strength of the preform, increasing the value of the preform as a structural member.

In conventional weaving, warp (lengthwise) yarns are alternately raised and lowered (a motion called "forming the shed"), and fill (weft or widthwise) yarns are inserted in the shed and beaten into the fell (the apex of the shed). Angle-ply weaving (see Figure 1) is based upon the movement of racks of needles and the corresponding angle yarns across the fabric as the fabric is being formed. The needles could be extended periodically to form a shed, analogously to the raising and lowering of the warp yarns in conventional weaving. The angle of the angle plies would be controlled via the speed of the motion of the needles across the fabric relative to the speed of advance of the fabric. Depending upon the layer-interconnection design, the angle-ply needles could be extended through the adjacent layer(s), and fill yarns inserted.

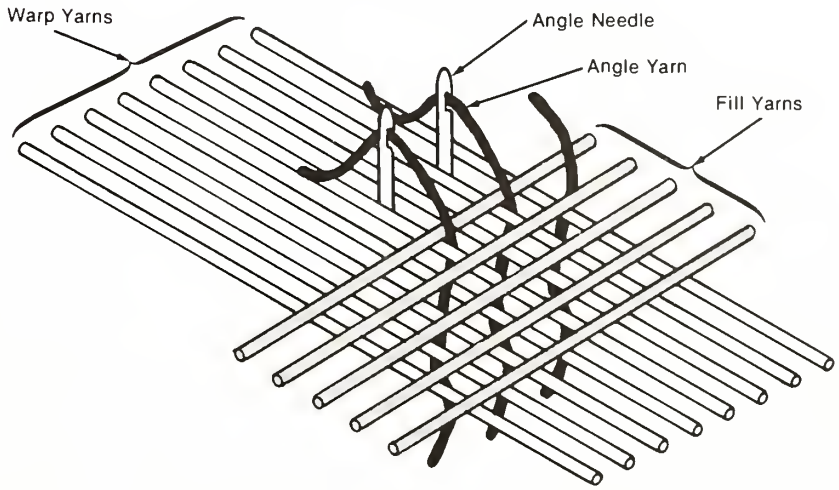
The needle-rack assembly (see Figure 2) would include needles (the angle-ply needles) in a holder moved along the rack. The needles could be extended pneumatically or electromagnetically. After the holder and its needles had moved to the end of the rack, the needle-and-holder assembly would be removed, and new angle-ply yarns would be inserted into the needles and remounted at the beginning of the rack. The angle-ply yarns would be wrapped around small spools mounted on the back of the needle holder. The yarns would be fed from the spools to the needles. A mechanism for rewinding and tensioning the yarn would be incorporated into each spool subassembly.

The ends of the angle yarns could be woven into the selvage of the preform or attached to an edge support moving at the same speed as that of the advancing fabric. The moving edge support could be simply a moving sticky belt against which the ends of the yarns would be pressed. Once an angle yarn was woven, it would be released (pulled) from the belt.

The various weaving mechanisms would be actuated by stepping motors and other electromechanical devices. The use of



BIAS-DIRECTION WEAVING ASSEMBLY IN CONVENTIONAL MULTIHARNESS LOOM (INSERTION OF FILL YARNS NOT SHOWN)



DETAIL OF NEEDLES EXTENDING BETWEEN WARP YARNS DURING INSERTION OF FILL YARNS

Figure 1. **Angle-Ply or Bias-Direction Weaving** could be incorporated into a conventional multiharness loom for making planar fabric with a bias weave.

state-of-the art microcomputers to control these devices would enable the selection of many different sequences of weaving motions to obtain the desired three-dimensional woven pattern.

This work was done by Gary L. Farley of **Langley Research Center.**

This invention is owned by NASA, and a patent application has been filed. Inquiries concerning nonexclusive or exclusive license for its commercial development should be addressed to the Patent Counsel, Langley Research Center. Refer to LAR-14048/TN.

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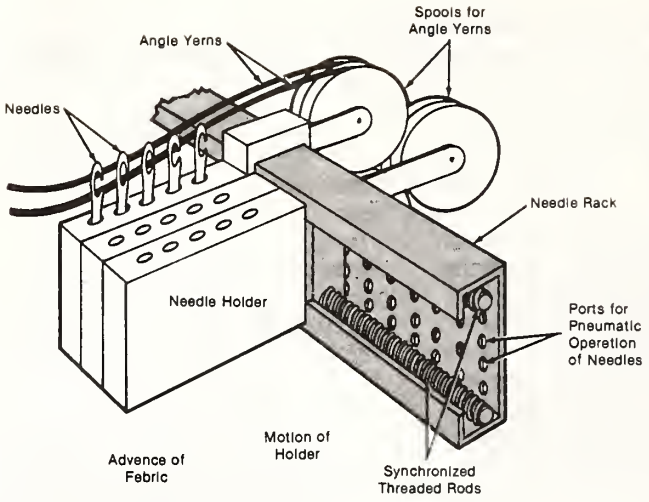

Figure 2. The **Needle-Rack Assembly** would feed the angle yarns to the fabric being formed. The needles in the holder would move along the rack (across the path of the advancing fabric).

FOR ADDITIONAL INFORMATION: *Contact: Director, Technology Transfer Division, P.O. Box 8757, BWI Airport, MD 21240; (301) 621-0100 Ext. 241*
REFER TO THE NUMBER LISTED AT THE END OF THIS ARTICLE

NASA Tech Brief
National Aeronautics and Space Administration

Calculating Masses, Densities, and Compositions of Alloys

Three simple computer programs perform routine metallurgical calculations.

The Metallurgical Programs include three simple programs that calculate solutions to problems common tc metallurgical engineers and persons making metal castings. The first program calculates the mass of a binary ideal mixture (alloy), given the weight fractions and densities of the pure components and the total volume. The second program calculates the densities of a binary ideal mixture. The third program converts the atomic percentages of a binary mixture to weight percentages. The programs use simple equations to assist with routine calculations.

The Metallurgical Programs are written in Microsoft QuickBASIC for interactive execution and have been implemented on an IBM PC-XT/AT operating on MS-DOS 2.1 or higher with 256 Kbytes of memory. All instructions needed by the user appear as prompts as the software is used. Data are entered by use of the keyboard only, and output is via the monitor. The Metallurgical Programs were written in 1987.

This program was written by H. de Groh for **Lewis Research Center.**
LEW-14914/TN

FOR ADDITIONAL INFORMATION

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NASA Tech Brief
National Aeronautics and
Space Administration

Computing Blood Flows

Methods developed for aerospace could be applied to the mechanics of biofluids.

A report argues for the use of advanced computational fluid dynamics to analyze flows of biofluids — especially blood. The development of supercomputers and fast flow-simulating algorithms has made computational fluid dynamics indispensible to aerospace research and design. The ability to simulate numerically and visualize complicated, time-varying three-dimensional flows can also contribute to the understanding of phenomena in the heart and blood vessels, thus offering the potential for the development of treatments for abnormal flow conditions.

The blood-flow problem is formulated via the Navier-Stokes equations for incompressible flow. Several alternative mathematical models of the viscosity tensor are presented. The transformation to generalized curvilinear coordinates that conform to the irregularly shaped and time-varying inner surfaces of blood vessels is discussed.

Methods for the solution of the Navier-Stokes equations are discussed. One method is based on the pseudocompressibility formulation, in which a small, fictitious compressibility is added to the equation of continuity to take advantage of fast, implicit numerical solution schemes that have been developed for compressible flows. Another is the fractional-step method, in which the discretized equations are advanced in time by decoupling the solution of the momentum equation from that of the continuity equation. Commonly in this method, one step is to solve for an auxiliary velocity field by use of an equation for the conservation of momentum in which the gradient of pressure is approximated by its value at the previous time step. In the next step, the pressure, which maps the auxiliary velocity onto a divergence-free velocity field, is computed. Other operator splittings can be adopted by treating the equation for momentum as a combination of convective, pressure, and viscous terms.

The next topic is the generation of computational grids. Because of branching and other complexities, in some cases flows can be divided into zones, within each of which the grid is suited to the local shape of the blood vessels. In other cases, the need for complicated interface procedures can be avoided by the use of published procedures for the generation of continuous grids.

The report presents the results of some computed bifurcated flows — simplified versions of a 90° branching off a blood vessel. As an example of the capabilities of computational fluid dynamics, the computed flow in a portion of the Space Shuttle main engine is also shown.

This work was done by D. Kwak, J. L. C. Chang, S. E. Rogers, and M. Rosenfeld of **Ames Research Center.** *Further information may be found in NASA TM-100089 [N88-21422], Price Code: A03 "Potential Applications of Computational Fluid Dynamics to Biofluid Analysis."*

Copies may be purchased from the National Technical Information Service, Springfield, Virginia 22161, Telephone No. (703) 487-4650. Rush orders may be placed for an extra fee by calling (800) 336-4700. *ARC-12253/TN*

FOR ADDITIONAL INFORMATION: *Contact: Director, Technology Transfer Division, P.O. Box 8757, BWI Airport, MD 21240; (301) 621-0100 Ext. 241*
REFER TO THE NUMBER LISTED AT THE END OF THIS ARTICLE

NASA Tech Brief
National Aeronautics and Space Administration

Effects of Rapid Crushing on Composites

Effects of crushing speeds on energy-absorbing capabilities of composites are studied experimentally.

An experimental study described in a NASA technical memorandum was performed to determine whether the crash energy-absorption capabilities of graphite/epoxy and Kevlar/epoxy composite materials are functions of the speed of crushing. An additional objective was to develop an understanding of the mechanisms of crushing. Composite materials are being proposed for application to aircraft and automotive structures to meet stringent contraints on weight and the costs of manufacture. Although composites can exhibit crushing modes significantly different from those of metallic materials, recent studies have shown that composites can absorb energy efficiently.

The majority of tests on composites have been performed under quasi-static crushing conditions (that is, slow crushing) to facilitate the understanding of crushing modes and mechanisms, while little is understood about the dynamic crushing characteristics. The reported study was intended to overcome this deficiency.

In the experiments, tubes of circular cross section were used as specimens because of their inherent stability and ease of fabrication, and for comparison with previous data. The tubular specimens were crushed at speeds between 10^{-2} and 12 m/s by a closed-loop, hydraulically actuated impact system (CLOHIS). In each experiment, the speed of crushing was maintained approximately constant. The maximum crushing force in the CLOHIS was 22 kN.

The crushing force and ram speed as a function of time were recorded on a fast storage-tube oscilloscope. A hydraulic power supply provided the means to propel the ram and crushing apparatus at the required speed. The ram was accelerated to the specified speed within the first few centimeters of its travel; after that, the tube specimen was crushed between the platens. Entrapped air was allowed to escape through holes incorporated into the system to minimize any air-spring effects that could occur during the dynamic crushing of tube specimens. Approximately 2,000 data points, evenly spaced in time, were recorded per ram-speed and crushing-force data channel.

On the basis of the results of these tests, the energy-absorption capability of the composite materials was determined to be a function of the speed of crushing. The magnitude of the effects of speed of crushing on energy-absorption capability was determined to be a function of the mechanisms that control the crushing process. The modes of crushing based upon the exterior appearances of the crushed tubes were unchanged for the composite materials. This technology could be applied to the enhancement of safety and crashworthiness of automobiles, the design of energy-absorbing devices in machinery, and problems that involve explosions and impacts.

This work was done by Gary L. Farley of the U.S. Army Aerostructures Directorate at **Langley Research Center**. *Further information may be found in NASA TM-89122 [N87-25438], Price Code: A02 "The Effects of Crushing Speed on the Energy-Absorbing Capability of Composite Material."*

Copies may be purchased from the National Technical Information Service, Springfield, Virginia 22161, Telephone No. (703) 487-4650. Rush orders may be placed for an extra fee by calling (800) 336-4700. *LAR-14087/TN*

FOR ADDITIONAL INFORMATION: *Contact: Director, Technology Transfer Division, P.O. Box 8757, BWI Airport, MD 21240; (301) 621-0100 Ext. 241*
REFER TO THE NUMBER LISTED AT THE END OF THIS ARTICLE

NASA Tech Brief
National Aeronautics and Space Administration
Marshall Space Flight Center, Alabama

Licensing Opportunity

Treating Nickel Alloy for Sonic Quality

Bars are processed to enable acoustic monitoring of stress.

A treatment makes bars of Inconel* 718 alloy homogeneous so that acoustic waves can pass through the material at constant velocity. By thus assuring sonic quality, the treatment makes possible accurate acoustic monitoring of preloads in fasteners made from the bars.

As received from the manufacturer, the bars contain local regions in which the chemical composition is different from that of the bulk of the bar. The speed of sound in these regions may be 2 to 3 percent higher than that in the bulk. The difference causes confusing patterns of distorted or multiple echoes when parts are monitored acoustically for stress, making it impossible to interpret the monitoring display.

The treatment eliminates longitudinal inhomogeneous regions by recrystallizing the bars. It consists of the following steps (see figure):

- Cold-draw a bar to reduce its diameter by 35 ± 5 percent.
- Anneal the bar at 1,900 °F (1,038 °C) for 30 minutes in a protective atmosphere of hydrogen or argon. Keeping the bar in the protective atmosphere, cool the bar to 1,650 °F (899 °C) in 10 ± 2 minutes, then to 1,470 °F (799 °C) in 20 ± 5 minutes, and finally to room temperature.
- Cold-draw the bar to reduce its diameter by another 35 ± 5 percent.
- Prior to production, heat-treat the bar in hydrogen or argon for 8 h at 1,325 °F (718 °C), then cool at 100 °F (56 °C) per hour to 1,150 °F (621 °C). Hold the bar at this temperature for 8 h, then cool it in air.

*"Inconel" is a registered trademark of the INCO family of companies.

This work was done by Donald E. Stuck, David Kramer, and Dan Q. Lam of Rockwell International Corp. for **Marshall Space Flight Center.**

Inquiries concerning rights for the commercial use of this invention should be addressed to the Patent Counsel, Marshall Space Flight Center. Refer to MFS-29594/TN.

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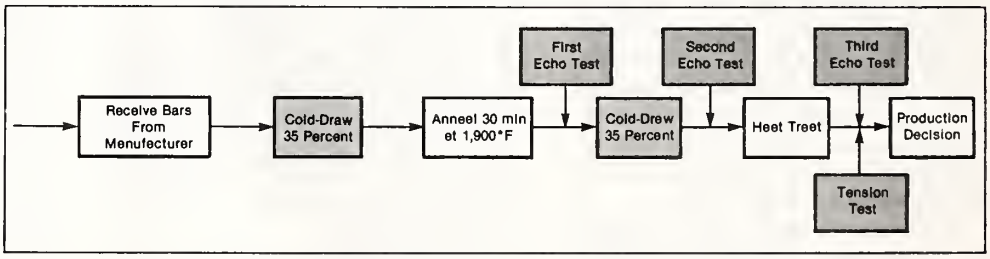
This **Combination of Thermal and Mechanical Treatments** provides Inconel* 718 bars of high sonic quality suitable for acoustic monitoring of preloads in fasteners made from the bars.



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REFER TO THE NUMBER LISTED AT THE END OF THIS ARTICLE

Sandia National Laboratory

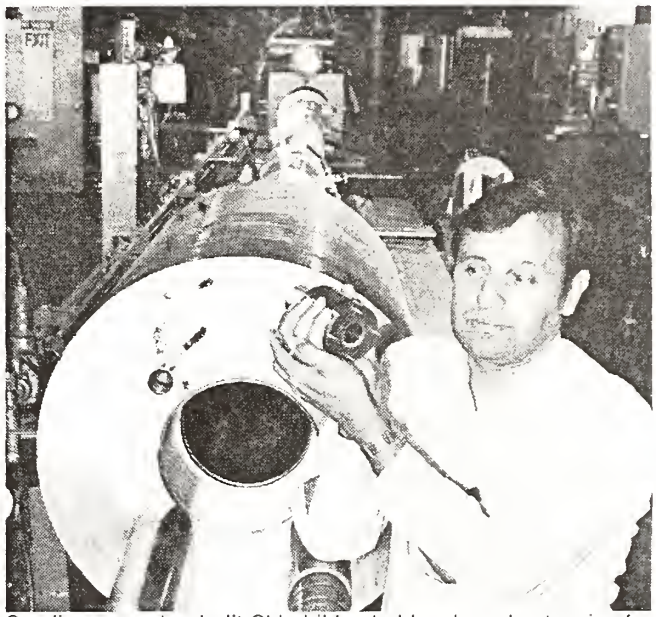
Technique Boosts Hypervelocity Materials Impact Testing

A new high-velocity technique is helping researchers at Sandia National Laboratories better understand and predict what happens when materials collide at high-pressure and high-temperature.

Scientists use several types of guns, or launchers, to study materials exposed to the "shock" pressures and temperatures resulting from high-velocity impacts. In such severe environments, materials can survive, fracture, melt, or vaporize, depending on their basic properties and the conditions of impact.

One near-term application is in the study of collisions between meteorites and space stations or other collisions that may occur in space, jeopardizing pressurized tanks or satellites. Other applications include advanced weaponry, armor, safety engineering, explosive forming, and explosive welding of metals.

High-velocity impact is currently the only method available for determining material responses at very high pressures and temperatures. Information on how materials flex, fracture, and fragment, and the kinds of debris created from these impacts are also learned from analysis of the experiments. This work, called equation of state research, is important to understanding the responses of materials subjected to shocks.



Sandia researcher Lalit Chhabildas holds a barrel extension for muzzle-end of light-gas Hypervelocity Launcher, used to achieve very high velocities for materials impact tests.

Disc speeds to 23,265 mph

Information obtained in laboratory impacts that may last one millionth of a second (one microsecond) helps researchers build computerized models of real-life phenomena, such as the penetration of armor. The further researchers can push the velocities, pressures and temperatures, the better the models will be for predicting what happens in actual impact events.

A variety of guns are used to hurtle thin discs, or fliers, and other projectiles at speeds from hundreds to thousands of miles per hour. New launchers are being designed at Sandia and elsewhere to extend this area of knowledge.

A Sandia light-gas gun used to accelerate projectiles was originally believed to have an upper velocity limit of 8 kilometers per second (17,900 miles per hour), explains Lalit C. Chhabildas of Sandia's Thermomechanical and Physical Division. To do so, gas pressures of about 10,000 atmospheres were used to drive the projectile. But a new technique has allowed researchers to accelerate one-gram fliers to speeds of 10.4 kilometers per second (23,265 miles per hour).

The secret to higher accelerations proved to be a graded-density impactor, or "pillow," at the front of a projectile, which strikes the flier plate. When the pillow is used, it cushions the plate's acceleration by preventing large shocks from forming, thereby preventing melting, vaporization, or other destruction of the flier.

High pressures in 24-foot barrel

Designed and fabricated at Sandia, the graded density impactors help shape the pulse as it is transmitted to the flier plate for acceleration through the smooth barrel of the launcher.

Sandia's gun, recently renamed the Hypervelocity Launcher, is capable of accelerating fliers weighing up to three or more grams. The process begins with the firing of a powder gun, which propels a heavy projectile into a rupture disc. This releases gas pressure into a smaller diameter, second-stage barrel. The pressure sends hydrogen gas bursting into the launch tube to push a

projectile containing the impactor down the 24-foot barrel. Impact of the pillow with the flier creates pressures 100 times higher than used in the past to launch plates to hypervelocities.

Very high pressures (a million times atmospheric pressure) have typically produced uneven loading that melts, vaporizes, or breaks the fliers apart in the 1 1/8-inch diameter (28mm) barrel. For this reason, only much lower pressures were used in the gun until development of the pillow impactor. The successful 10.4 kilometer per second experiments used an aluminum flier plate, but other materials are also being studied.

Materials scientists look for materials, such as new light-weight armors, that can withstand certain impacts or strains to meet the demands on engineering designs they may be working with. Increasing laboratory capabilities mean this work can be done more successfully and quicker, Chhabildas explains. "Before we had to make educated guesses about the response of materials to hypervelocity impact. Now we're on much firmer ground with data to back up engineering designs."

The science of shock compression has grown steadily since World War II as instruments to detect shock-wave profiles have improved. At Sandia's Shock Technology Applied Research (STAR) facility, scientists use optical, electromagnetic, and other techniques to understand these sudden impacts. □

FOR ADDITIONAL INFORMATION

Public Information Division,
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Refer to announcement 25 No. 8

Advanced Field NDE System Producibilty, Advanced Real-Time Inspection System

Southwest Research Institute (SWRI) has established a portable, advanced real-time inspection system (ARIS) to perform ultrasonic "C" scan of aircraft composite structures—that is, fiber-matrix and honeycomb. ARIS provides automated, simultaneous recording of ultrasonic inspection data and search unit position during a manually scanned inspection of composite and bonded structures. Depth of a defect or amplitude of the signal is displayed by a color shade. The 4 foot by 4 foot coverage is adequate in most cases. ARIS also can be disassembled into modules and packed for transportation as a piece of airline baggage.

A preproduction ARIS system has undergone an extensive evaluation program by SWRI and has been field tested with excellent results. Changes and additions to the hardware and software considered necessary or advisable were accomplished. Four production systems have been delivered to the Air Force.

ARIS systems are now in use at Wright-Patterson AFB, McClellan AFB, and Edwards AFB. The preproduction system is now on loan to SWRI.

Technology transfer has occurred with the purchase of ARIS by American Airlines. Other airlines, such as the South Korean Air Force, the Israeli Air Force, the RAF, the RAAF, and others have expressed interest in ARIS. The preproduction unit at SWRI is expected to be placed in operation at the Warner Robins Air Logistics Center.

ARIS capability improves inspection reliability and documentation and ensures adequate structural integrity of bonded and advanced composite aircraft structures. Thorough and reliable inspection of parts results in many aircraft remaining in-service or returned-to-service; these aircraft may have been pulled from operational status with the use of less adequate inspection equipment. ARIS also provides a permanent record that identifies changes in flaw size and configuration over a period of aircraft operation.

FOR ADDITIONAL INFORMATION: To discuss this effort further, contact: Project Engineer: Edward Wheeler, Air Force Manufacturing Technology Program, ATTN: AFWAL/WRDC/MTPM, Wright Patterson AFB, OH 45433-6533; (513)255-5151. Refer to contract: F33615-83-5066.

Medicine & Biology

0203 Growth Factor Linked to Tumor Growth

0204 Nickel-Silicon Alloys Improve Cancer Therapies

0205 Separation of Chromosomal Length DNA Molecules: Pneumatic Apparatus for Rotating Gels During Electrophoresis

0206 Cloning of Spider Silk Gene

0207 Clothing Design for People with Special Needs

0208 The Directory of Biotechnology Information Resources

Testing & Instrumentation

0209 The In-Vivo Generator for Radioimmunotherapy

0210 Ultrasonic Imaging of Deep Arteries—Swept-frequency sound replaces pulsed sound. (Licensing Opportunity)

Other Items of Interest

0215 Particle Sizer Bridges Gap Between Visible Light and X-Rays

Lawrence Berkeley Laboratory

Growth Factor Linked to Tumor Growth

Cell biologists at Lawrence Berkeley Laboratory have discovered that a wound-associated protein, "transforming growth factor beta," can play an important role in creating an environment conducive to the formation of cancerous tumors.

LBL researchers have long contended that tumors are not caused simply by the presence of cancer-causing genes: The host microenvironment also plays a crucial role.

Now, a close look at that environment by Mina Bissell and Michael Sieweke of the Laboratory's Cell and Molecular Biology Division supports the contention that tumor formation is not a simple, one-step event. The results of the study, carried out in collaboration with colleagues at the National Cancer Institute, were recently published in Science magazine.

Most cancer research in the past 15 years has focused on the role of oncogenes, or cancer-causing genes, Sieweke says. But according to findings by Bissell and her associates more than a decade ago, cancer development by oncogenes in animals as well as humans is a multi-step process analogous to chemical carcinogenesis.

In this study, researchers worked with the RSV-virus and its oncogene, known as "src." TGFbeta was carefully injected into RSV-infected chicks in small doses via very fine needles so injury would be minimized. Tumors formed according to the levels of TGFbeta applied. Other growth factors the researchers tested did not elicit the same response. The study concluded that TGFbeta is indeed a "molecular mediator of wound tumor formation" and "can substitute completely for wounding in tumor induction.

"There may be other factors," Sieweke says, "but this one is certainly crucial." He cautions, however, that TGFbeta is "a curious factor. It has different effects on different cell types." For example, it stimulates the growth of fibroblasts but it inhibits most epithelial cells.

"Most of the vicious cancers in humans are carcinomas," says Sieweke - cancers that develop from the epithelial, or outer, cells. Because TGFbeta inhibits the growth of the epithelium, says Sieweke "at first people were excited" about its potential in the treatment of those deadly carcinomas. But while it may inhibit the epithelial cells, the underlying cells may be stimulated to create an environment favorable to tumor growth.

Because of the multifaceted effects of TGFbeta, caution must be exercised before clinical application, says Bissell, although TGFbeta may be beneficial in treating severe wounds. And Sieweke hopes the importance of looking closely at the different effects of TGFbeta will be clear to other scientists through the publication of these results.

"Many researchers have focused on the inhibitory role of TGFbeta," says Sieweke. "This is one of the first studies that focuses on its role in tumor growth."

FOR ADDITIONAL INFORMATION: Lawrence Berkeley Laboratory, Public Information Department, 1 Cyclotron Road, Berkeley, CA 94720; 415/486-5771.

Ames Laboratory

Nickel-Silicon Alloys Improve Cancer Therapies

Working with the Department of Radiation Oncology at the University of Arizona, Ames Lab metallurgists have fabricated wires that are proving effective in the treatment of malignant tumors in the brain and other parts of the body. The wires are inserted into a thin plastic catheter that is then implanted in the patient's tumor. The patient is placed within an oscillating magnetic field which causes the wires, which are ferromagnetic, to heat up. Clinical studies indicate that the application of this technique, known as hyperthermia, in conjunction with radiation therapy, can be twice as effective as treatment by radiation or chemotherapy alone.

The use of inductively heated ferromagnetic wore implants is an effective means to produce hyperthermia (temperature above 42 degrees C), localized to the tumors. Just as elevated temperatures (evidenced by a fever) increase the body's ability to metabolize and destroy infectious cells, elevated temperatures in a tumor will make the cells more susceptible to damage that can be inflicted by radiation. However, physiological variables such as the region's bloodflow, and where the wires should be placed within the tumor demand a range of different treatment temperatures. Achieving the desired temperature depends on the amount of alloying element incorporated in the wire.

The Ames Laboratory Materials Preparation Center produced various alloys of wires with Curie points within a few degrees of each other. The Curie point is the critical temperature at which a material's magnetic properties change. Below this temperature, a magnetic field will cause the wire to heat up; however, above the critical temperature, the wire loses its magnetic property and cools. Thus, near the Curie point, the wire acts like a thermostat and regulates its own temperature. The wires were subjected to assay by analytical chemistry to ensure homogeneity of the composition along the length of the wire. Further research by Ames Lab scientists suggests that the size of the crystal grain boundaries may be a critical factor for obtaining consistent and reproducible results when the wire is implanted in the tumor.

In addition to work in progress at the University of Arizona, patients at the University of California's Medical Center in San Francisco, and at the City of Hope Medical Center near Los Angeles have begun receiving the hyperthermia treatment. Goals for the project include establishing a scientific base for determining whether hyperthermia, when used in conjunction with radiation or chemotherapy, is a valid cancer therapy.

Literature: None.

Patent/License Status: None.

Potential Applications/Spinoffs: Cancer therapy.

FOR ADDITIONAL INFORMATION: Contact Daniel E. Williams, Office of Research and Technology Application, Ames Laboratory, 119 Office and Laboratory, Iowa State University, Ames, IA 50011; (515)294-2635.

Brookhaven National Laboratory

Separation of Chromosomal Length DNA Molecules: Pneumatic Apparatus for Rotating Gels During Electrophoresis

Rotating gel electrophoresis is one form of alternating field direction gel electrophoresis, a procedure that has been developed to operate very long DNA molecules. This technology is useful in mapping the human and other large chromosomes. Our design has been adopted by a local small business.

Description of Technology: Uses an inexpensive pneumatic actuator to replace an expensive stepping motor to rotate gels during electrophoresis. Reduces total cost of gel apparatus by about 50%.

Literature: J.C. Sutherland, A.B. Emrick, J. Trunk, Separation of Chromosomal Length DNA Molecules: Pneumatic Apparatus for Rotating Gels During Electrophoresis, Biology Department, Brookhaven National Laboratory, Upton, NY.

FOR ADDITIONAL INFORMATION: Dr. William Marcuse, Office of Technology Transfer, Building 902-C, Brookhaven National Laboratory, Upton, NY 11973, Commercial (516)282-2103. Refer to BNL/AA-48.

Cloning of Spider Silk Gene

Some years ago Natick studied the mechanical properties of a variety of spider silks, so that the strongest silks could be isolated for further study of ballistic protective fiber applications. The golden orb weaver spider's dragline silk, one of at least six different silks produced by this spider, was determined to possess unusually high tensile strength and extensibility. Today, Natick scientists have reinstituted this research because of the new tools available in biotechnology, which allows the production of large quantities of the silk. This work, which was recently highlighted at the American Association for the Advancement of Science meeting, resulted in the successful isolation, characterization, and cloning of a spider silk gene that may be the foundation for a new family of ballistic protective clothing. The research accomplishments have been internationally recognized with requests for presentations in Finland and Germany. The successful cloning of this gene is just the first step towards large-scale production of this polymer. Research is continuing into the molecular structure of silk and the genetic controls of its synthesis, with the goal of engineering the native gene to produce a series of fibers with a prescribed set of properties and functions. This engineering will allow many additional potential applications, as well as provide a series of well-defined and controlled polymers for the detailed study of ballistic behavior.

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U.S. Army Research

U.S. Army Natick RD&E Center, Natick, MA 01760

Clothing Design for People with Special Needs

Currently the clothing needs of people with physical disabilities and limitations are not adequately addressed by mainstream designers and manufacturers. If garments do exist, the selection is often limited, they can only be purchased through the mail, and they are designed to meet the physical requirements of the average wheelchair user or the average person with arthritis. In addition, as disabilities vary in their cause, stage of development, and effect on the individual's facility with dressing and performing other basic functions, each physical limitation, or combination of limitations, requires a different solution.

Evidence suggests that custom-designed garments are ideal for meeting special needs. Traditional methods for producing custom garments, however, are time and labor intensive, and results are expensive, one-time solutions. Fortunately, recent developments in personal computer technology can now put custom clothing within the reach of the disabled population.

Those who will directly benefit from this technology include people with disabilities that are characterized by functional limitations in the hand and arm, limited range of motion and limited overall body strength (i.e., arthritis and spinal cord injury). This technology can also be applied to anyone with a unique body shape or a particular fitting problem such as those associated with aging, curvature of the spine, amputation, or the use of a wheelchair.

Since the project's inception, the development team at the VA Rehabilitation R&D Center in Palo Alto, California, has worked toward applying flat pattern drafting techniques in a computer-aided design environment. AutoCad (AutoDesk) and Synthesis (TransformerCAD) have been selected as the software tools. AutoCad is a microcomputer-based computer-aided design package. Synthesis, which works in conjunction with AutoCad, allows a designer to change master drawings via information stored on a spreadsheet.

Some investigation into three-dimensional modeling of musculoskeletal anatomy occurred as part of the initial development effort. For example, they designed a 3D wireframe human model that can be scaled about different axes to create a variety of body types. The model has link-end pivots that permit rotation in user-defined planes and ranges of motion.

The intent of the project is to demonstrate that CAD technology can be used to design well-fitting clothing that is appropriate to the needs of people with disabilities. The specific goals are: (1) to collect sufficient human factors and anthropometric information (such as height, weight, body girths and lengths) to set up a simple database; (2) to create a link between that database and the CAD environment; and (3) to test this system by producing patterns and clothing samples for several different sets of anthropometric data.

The focus is on overall system development and the generation of accurate digital and graphic representations of the human body for use in garment design and construction. More specifically, basic flat patterns and two-dimensional images are being created from standards currently used by the home sewing industry. Anthropometric information will be gathered as part of a study to develop garments for use in patient rehabilitation. They are also investigating different ways of taking human body measurements. It will be important to determine the quantity, as well as the quality, of measurements that are necessary to produce a custom fit.

Once sufficient data is acquired for an individual, a flat pattern can be drafted and a test garment constructed. Appropriate changes will be made to the pattern, as necessary, to achieve a fit.

Current efforts are on developing garments for use in patient rehabilitation. Researchers are collaborating with occupational therapists and doctors in the spinal cord injury and rehabilitation medicine clinics at the Palo Alto VA Medical Center. The hope is to quantify some of the work that has already been done in the clinics while investigating new concepts in custom clothing design.

Researchers are currently developing specifications, such as fabric requirements and sewing instructions, for altering ready-to-wear garments. They are also drafting a pattern for a halo shirt to be worn by newly injured spinal cord patients that require neck stabilization. Once it is on the computer system, the basic halo pattern can be easily customized for individual patients.

Future projects include a clothing needs survey and a "visual" questionnaire and capability profile for ADL (activities of daily living) evaluation. Both of these applications will be developed using HyperCard, a graphic and textual information organizer for the Macintosh computer.

FOR ADDITIONAL INFORMATION: Anyone interested in further information can contact Al Sacks, (415)858-3991; or Robert Rosenkrans, Technology Transfer Coordinator, U.S. Army Natick RD&E Center, Natick, MA 01760-5014; (508)651-5296.

NIH
Research & Technology
U.S. Department of Health and Human Services Public Health Service National Institutes of Health

The Directory of Biotechnology Information Resources

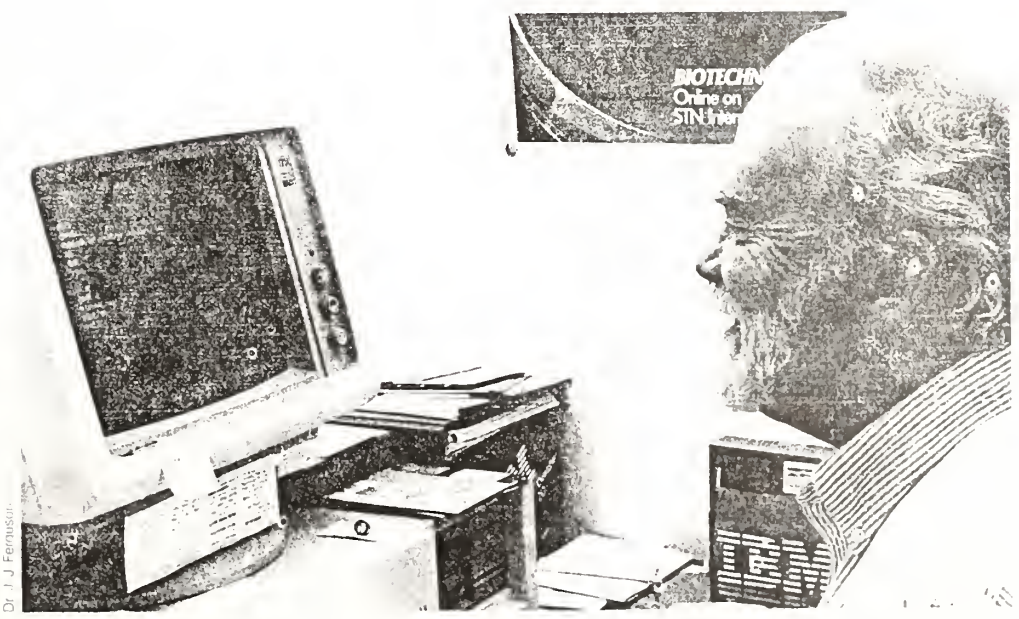
The Directory of Biotechnology Information Resources (DBIR) offers researchers and businesses easy access to a wide array of information about national and international biotechnology resources, according to Dr. James J. Ferguson, Jr., special expert at the National Library of Medicine (NLM) in Bethesda, Maryland.

"All that is needed for finding these resources is a computer with a modem," Dr. Ferguson says.

The DBIR, which was established in 1989 and is funded solely by the NLM, contains over 1,400 separate descriptions, or unit records, of information resources that describe a broad spectrum of biotechnology resources relating to medicine, agriculture, pharmaceuticals, food technology, microbiology, environmental sciences, and molecular biology.

Each unit record is filed under one of four categories. The first includes descriptions of data bases, data base vendors, bulletin boards, and networks. The second consists of collaborative research organizations concerned with biotechnology and molecular biology as well as collections and repositories of biologic materials such as microorganisms and genetic elements. The third category of files contains descriptions of literature pertaining to biotechnology and molecular biology such as books, manuscripts, annual reviews, compendia, tables, and major journals. The fourth file category is a listing and description of committees involved in establishing a standard nomenclature for a particular aspect of biotechnology or molecular biology.

DBIR unit records are each subdivided into 28 fields. These fields, which characterize the resource being described, are in turn grouped into four categories: administrative information, resource identification, keyword/descriptors, and data type specific information. The administrative information fields give a general description of the



Dr. James J. Ferguson is reviewing an entry in the new data base called the Directory of Biotechnology Information Resources.

record such as its number, length, and how recently it was updated. The resource identification fields provide information such as the name, address, telephone and FAX number of the resource. The keyword/descriptors fields provide a general description of the resource plus special key words and assigned NLM Medical Subject Heading (MeSH) terms. Finally, the data type specific information fields provide more detailed information about the resource such as publications it may produce.

Despite the wealth of information contained in the DBIR unit records, Dr. Ferguson emphasizes that it was not designed to be an all inclusive data base. He notes, for example, that although the directory lists major journals and books, it doesn't give references to particular articles.

"It's not a bibliographic data base," he explains. "Instead, it is something that one turns to in order to be led into other kinds of information. It's more like a 'Yellow Pages' of biotechnology resources," he says.

The DBIR is particularly suited for research scientists, Dr. Ferguson suggests. "We see this primarily as something scientists would use to find out which resources are available to support the work they're doing. We expect, however, that people in the commercial side of biotechnology also will be interested in getting access to this information."

The information in DBIR is assembled and maintained under contract by the bioinformatics department of the American Type Culture Collection (ATCC) in Rockville, Maryland. According to Dr. Ferguson, ATCC personnel update the directory on a monthly basis. The NLM and ATCC also solicit information from researchers and businesses about new resources that can be added to the directory.

"Through public meetings and articles we invite people to submit descriptions of resources that might fit into one of our four categories," Dr. Ferguson explains.

DBIR can be accessed electronically via the NLM's TOXNET (Toxicology Data Network) system. DBIR is also accessible as a subfile of DIRLINE, the Library's directory of Information Resources Online, a broad-based directory information data base. Dr. Ferguson explains that the only prerequisite for accessing DBIR is a personal computer with a modem and an NLM user ID, which can be obtained from the MEDLARS Management Section of the NLM at no cost.

The basic cost for accessing DBIR is approximately $25 per hour during the day and approximately $18 per hour at night.

For more detailed information on DBIR contact:
Dr. James J. Ferguson, Jr.
Specialized Information Services
National Library of Medicine
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Bethesda, MD 20894
Telephone: (301) 496-6531

To obtain an NLM User ID contact:
MEDLARS Management Section
National Library of Medicine
8600 Rockville Pike
Bethesda, MD 20894
Telephone: (800) 638-8480

For submission of information to the DBIR contact:
Carole Brown
American Type Culture Collection
12301 Parklawn Drive
Rockville, MD 20852
Telephone: (301) 231-5528

Brookhaven National Laboratory

The In-Vivo Generator for Radioimmunotherapy

The technology involves labeling monoclonal antibodies with intermediate half-life radionuclides which decay to much shorter half-life daughters with desirable high energy beta emissions. Since the daughter will be in equilibrium with the parent, it can exert an in-situ tumoricidal effect over a prolonged period in a localized fashion, essentially as an "in-vivo generator". This approach circumvents the inverse relationship between half-life and beta decay energy.

The number of viable candidate radionuclides for radioimmunotherapy having both the desired high beta energy and half-life comparable to antibody uptake kinetics is limited by an inverse relationship between half-life and beta decay energy. This approach overcomes this restriction and would allow a wider selection of radionuclides for effective radioimmunotherapy.

Literature: L.F. Mausner, R.F. Straub, S.C. Srivastava, Production and Use of Prospective Radionuclides for Radioimmunotherapy, pp. 149-163, in *Radiolabeled Monoclonal Antibodies for Imaging and Therapy*, Plenum Press, New York, 1988; The In-Vivo Generator for Radioimmunotherapy, J. Labelled Compounds, Radiopharmaceutical, 2C, 498 (1989).

Patent Number and Patent License Status: Statutory Invention Registration #H545, Published November 1, 1988.

FOR ADDITIONAL INFORMATION: Dr. William Marcuse, Office of Technology Transfer, Building 902-C, Brookhaven National Laboratory, Upton, NY 11973, Commercial (516)282-2103. Refer to BNL/AA-49.

NASA Tech Brief
National Aeronautics and Space Administration
NASA's Jet Propulsion Laboratory, Pasadena, California

Licensing Opportunity

Ultrasonic Imaging of Deep Arteries

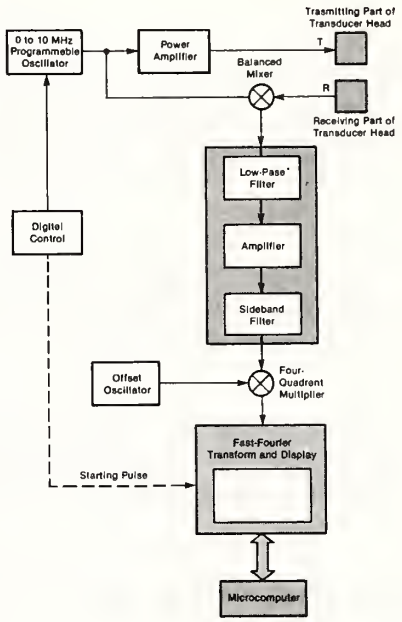
Swept-frequency sound replaces pulsed sound.

An ultrasonic medical instrument produces images of peripheral and coronary arteries with resolutions higher and at depths greater than those attainable by previous ultrasonic systems. The instrument is intended for use in the noninvasive detection and measurement of atherosclerotic lesions.

Conventional pulse-echo ultrasound imagers are now approaching the limits of their resolution for deep-lying arteries. Pulses are severely attenuated at high frequencies as they penetrate deeply into tissue, and their echoes therefore have poor signal-to-noise ratios. The farther the pulses penetrate, the less the image information that can be extracted from them.

The new instrument uses time-delay spectrometry; it transmits sound continuously as its frequency is swept, detects the reflected sound by heterodyning, and analyzes the spectrum of the reflected sound. Echoes arrive at the receiver with a delay that depends on the length of the transmission path and the speed of propagation. Because the transmitted frequency is swept, the delay corresponds to a frequency offset. Thus, by selecting an appropriate offset frequency and bandwidth, an equivalent interval of time or distance into the tissue can be selected.

A major benefit of the time-delay spectrometry system is that it transmits over a wide, controlled range of frequencies while using a matched filter in the receiver. The matched filter yields the best possible signal-to-noise ratio in the white-gaussian-noise environment typical of tissue measurements. It has been calculated that a version in which the frequency is swept from 0 to 10 MHz in 20 ms yields a 53-dB improvement in processing gain over that of a pulse-echo system that uses the same peak transmitted power.



The **Time-Delay-Spectrometry Imager** includes scanning, image-processing, and displaying equipment. It sweeps in frequency from 0 to 10 MHz in 20 ms, pauses for 5 ms, and repeats the sweep.

The instrument is illustrated schematically in the figure. An ultrasonic signal at a linearly swept frequency is transmitted into the tissue. The received signal is coherently mixed with the input signal and low-pass filtered to remove unwanted high-frequency components. A fast Fourier transform converts the remaining frequency components into a display in which the horizontal axis represents time (or, equivalently, range or depth) and the vertical axis represents intensity of the return signal. An image of the tissue can be generated by scanning the ultrasonic transducer across the surface of the tissue. Images are relatively free of the clutter and speckle that plague most ultrasound images.

Most of the spectral information is collapsed to form an image. The information remains in the instrument, however, and can readily be obtained when needed.

The new instrument does not yet operate in real time. Images must be averaged over several cardiac cycles, with some loss of resolution because of the movement of tissue. However, with faster digital electronics and improved ultrasonic transducers, the instrument will be able to produce images in real time, and the resolutions of images will be even better.

This work was done by James A. Rooney, Richard C. Heyser, and Dennis H. LeCroissette of Caltech for **NASA's Jet Propulsion Laboratory.**

This invention is owned by NASA, and a patent application has been filed. Inquiries concerning nonexclusive or exclusive license for its commercial development should be addressed to the Patent Counsel, NASA Resident Office-JPL. Refer to NPO-17439/TN.

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REFER TO THE NUMBER LISTED AT THE END OF THIS ARTICLE

Natural Resources Technology & Engineering

0211 Differential Radar Interferometry Maps Changes in Elevation—Vertical earthquake motions as small as 1 cm are detectable. (Licensing Opportunity)

Software

0212 Computerization of the Decisionmaking Framework for Management of Dredged Material

Other Items of Interest

0169 Applications of Fluids Modeling to Assessment and Remediation of Hazardous Waste Sites

NASA Tech Brief
National Aeronautics and Space Administration
NASA's Jet Propulsion Laboratory, Pasadena, California

Licensing Opportunity

Differential Radar Interferometry Maps Changes in Elevation

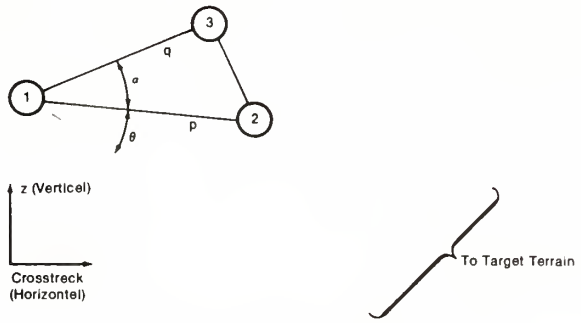
Vertical earthquake motions as small as 1 cm are detectable.

Differential radar interferometry can measure changes as small as 1 cm in the elevation of terrain across a swath as wide as 50 km, with a typical horizontal resolution of 10 m. This technique could be used to make extensive, accurate maps of such geophysical phenomena as heaving and buckling in fault zones, motions of tectonic plates, residual displacements from earthquakes, motions from prevolcanic swelling, motions of glaciers, tides, and even thermal expansion of mountains from diurnal heating.

Differential radar interferometry uses data from synthetic-aperture radar (SAR). Typically, three or more SAR images are formed by making passes at different times along three or more tracks that are usually separated slightly (see figure). The separate images are resampled to make them register with each other accurately. For each picture element in one of the SAR images, the differences are taken between the phase of the radar return signal and the phase of the return signal in the corresponding picture elements of the other two images. This yields two interferograms (phase maps) in which information on changes in elevation is scrambled with other topographical information.

After some further processing, the differences between the phase differences expressed in corresponding picture elements of the two interferograms are computed to produce a third, "double-difference" interferogram. The double-differencing operation removes the components of phase due to the underlying topography, leaving nonzero phases only in areas where the surface of the Earth has moved between the times of the observations. These phases can be used to deduce the amount of motion that has occurred. (The phase images also include noiselike local components due to such activities as excavation and building between observation times, but where the phase of many adjacent picture elements include a component common to all, that component indicates a shift in the terrain.)

Three Passes of synthetic aperture radar yield three amplitude-and-phase images, from which two interferograms (phase-difference images) are made. The two interferograms are used to make a third, "double-difference" interferogram that indicates vertical motion of the terrain between passes.



Difference Between Pheses In First and Second Passes: $\Delta\phi_{12} = (4\pi/\lambda)p\cos(\theta)$
Difference Between Phases In First end Third Passes: $\Delta\phi_{13} = (4\pi/\lambda)q\cos(\theta+\alpha)$
(λ = Wevelength)

The technique was tested in the Imperial Valley of California — an agricultural area where the surface is frequently disturbed by plowing, resulting in noiselike phase characteristics. The double-difference interferogram showed that between observations, phases changed in a coherent manner across entire fields. The changes are attributed to swelling of the ground when it is irrigated and shrinking when the water evaporates. The changes were found to be consistent with those expected on the basis of irrigation records for 48 out of 52 sites in the SAR images.

This work was done by Andrew K. Gabriel, Richard M. Goldstein, and Howard A. Zebler of Caltech for **NASA's Jet Propulsion Laboratory.**

This invention is owned by NASA, and a patent application has been filed. Inquiries concerning nonexclusive or exclusive license for its commercial development should be addressed to the Patent Counsel, NASA's Resident Office-JPL. Refer to NPO-17831/TN.

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REFER TO THE NUMBER LISTED AT THE END OF THIS ARTICLE

U.S. Army Fact Sheet

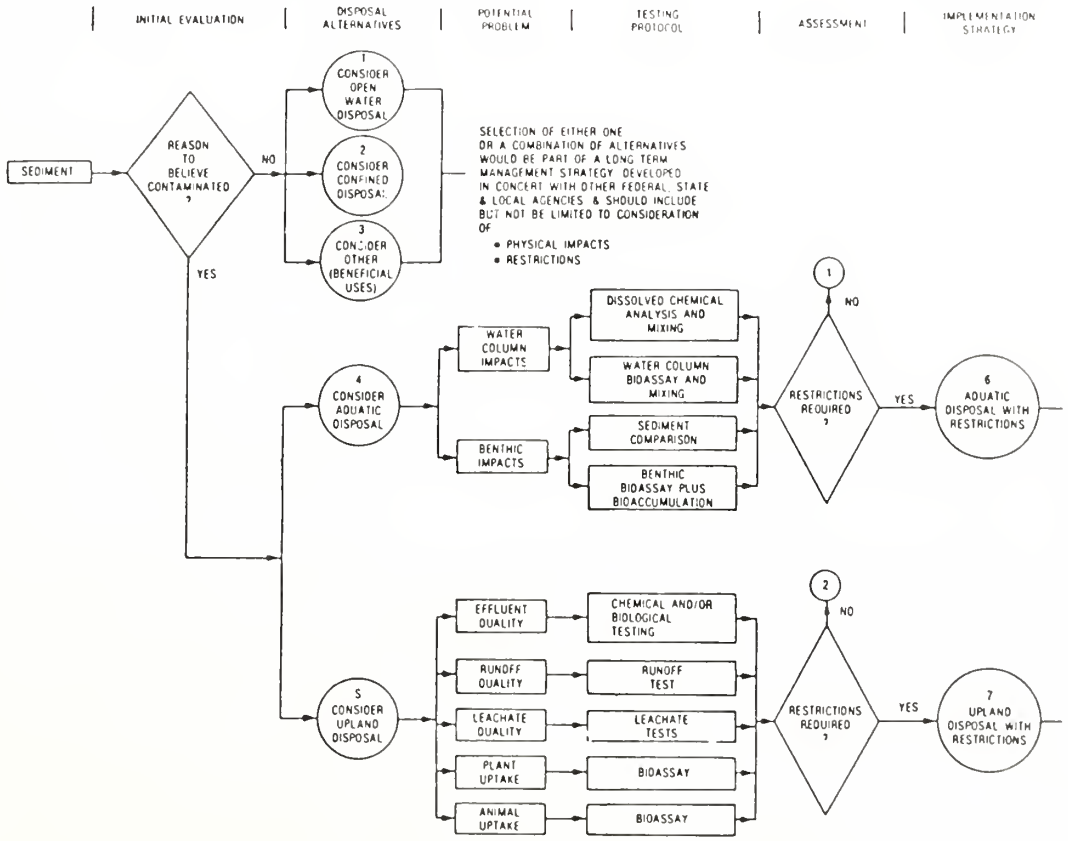
Computerization of the Decisionmaking Framework for Management of Dredged Material

The general Decisionmaking Framework (DMF) for management of dredged material (Peddicord and others 1986) was developed to provide a systematic approach for selecting the best option for placement of dredged sediments based on environmental concerns, cost, and site availability. Using a tiered testing approach, the DMF first guides the user to a decision as whether there is a "reason to believe" sediment contamination may require disposal restrictions. The tiered approach allows the necessary and sufficient level of testing to be used for each specific project.

In tier I testing, existing information and simple, inexpensive procedures are used to determine potential environmental impact. Later tiers are implemented if the initial results show a potential for impact or if they are inconclusive. This minimizes excessive testing and results in more efficient completion of required evaluations and reduced costs (Environmental Protection Agency/US Army Corps of Engineers 1977).

If a "reason to believe" exists, the DMF then identifies the data requirements necessary for further decisionmaking regarding suitability of the material for the chosen placement option. The user provides data from chemical analysis of the sediments proposed for dredging and from reference sediments, data from bioassays and bioaccumulation evaluations, and data describing the physicochemical nature of disposal site environments. Decision–enabling criteria that are locally determined or are provided by national standards are applied to the input data using a series of flowcharts that lead to the environmentally desirable placement option.

The Environmental Laboratory, US Army Engineer Waterways Experiment Station (WES) is preparing



Flowchart showing the pathways of the Decisionmaking Framework (from Peddicord and others 1986)

computer software that will greatly increase the speed and ease of application of the DMF for individuals who manage dredged material. The DMF flowchart is illustrated in Figure 1. Each block is subdivided into secondary flowcharts that implement detailed areas of the DMF. Computerizing the DMF procedure frees the user from separate data record keeping, mathematical calculations, and comparisons. Using predictive models, experimental data from the literature, and data entered or selected by the user, the DMF computer program will provide the user with summaries and guidelines to assist in making appropriate dredged material placement decisions. Once the necessary data have been entered into the program, results may be obtained in minutes instead of hours or days.

The current computerization effort covers tier I testing ("reason to believe" and the comparison of test and reference sediments), but more importantly, it provides a "front end" and uniform data entry platform for the integration of the test modules. These modules implement the various testing protocols needed to determine the applicability of available placement options. The test modules are being developed under various other programs.

Computer and Data Requirements

The DMF is being developed on an 80286 IBM PC AT compatible microcomputer with 640–kilobyte random access memory, 20–megabyte hard drive, and an EGA color monitor. This configuration is generally available to potential users and will provide sufficient computer power to perform the required computations at reasonable speed. A printer is not needed to use the program but is recommended for documentation of the results.

The DMF computer software will be released as a compiled, executable program that will not require any other software except MS or PC DOS (3.0 or higher) for the microcomputer operating system.

The DMF computer software allows the user to easily navigate through the flowcharts and will display prompts identifying required data inputs before proceeding to the next step. The first time this software is used on a test sediment, the user is required to provide bulk chemical analysis of the test sediments and of a reference sediment. Once these data are entered into the program, they are automatically saved on disk as discrete data bases and may be recalled for future use. Depending upon which module is chosen, other specific data, such as bioassay or bio–accumulation test results, may be required. Once they have been entered, data may be shared among all modules without the need for reentering. This feature will also allow the user to investigate multiple disposal alternatives with minimal effort.

The DMF will be compatible with the Automated Dredging and Disposal Alternatives Management System (ADDAMS) developed at WES and will be incorporated into it in the future (Schroeder 1988).

References

Environmental Protection Agency/US Army Corps of Engineers, Technical Committee on Criteria for Dredged and Fill Material. 1977 (July). "Ecological Evaluation of Proposed Discharge of Dredged Material into Ocean Waters; Implementation Manual for Section 103 of Public Law 92–532 (Marine Protection, Research, and Sanctuaries Act of 1972)," (Second Printing April 1978), Environmental Effects Laboratory, US Army Engineer Waterways Experiment Station, Vicksburg, MS.

Peddicord, Richard K., Lee, Charles R., Palermo, Michael R., and Francingues, Norman R., Jr. 1986. "General Decisionmaking Framework for Management of Dredged Material; Example Application to Commencement Bay, Washington," Miscellaneous Paper, US Army Engineer Waterways Experiment Station, Vicksburg, MS.

Schroeder, Paul R. 1988. "Automated Dredging and Disposal Alternatives Management System (ADDAMS), User's Guide," Draft Instruction Report, US Army Engineer Waterways Experiment Station, Vicksburg, MS.

FOR ADDITIONAL INFORMATION: Dr. Robert M. Engler, U.S. Army Engineer Waterways Experiment Station (CEWES-EP-D), 3909 Halls Ferry Road, Vicksburg, MS 39180-6199, or call 601/634-3624.

Physical Sciences

Testing & Instrumentation

0213 Compact Double-detector Radiation Monitor

0214 Dead-time Compensation Circuit for Radiation Survey Meter

0215 Particle Sizer Bridges Gap Between Visible Light and X-Rays

0216 Inexpensive Frequency Calibration Service Available

0217 Electrostatic Dispersion of Drops in Clusters—Electrical charging can speed evaporation.

0218 Linear Ion Trap for Atomic Clock—Second-order Doppler shift of the ion absorption frequency is reduced

0219 More About Evaporation in Cluster of Drops—Several mathematical models are used to study transport of species, mass, and heat.

Testing & Instrumentation

0220 Monitoring Small Deformations in an Instrument—Relatively simple source/detector pairs measure changes that affect optical alignment.

0221 Processing Laser-Velocimetric Data by Vector Scanning—Velocity plots can now be obtained in minutes instead of hours. (Licensing Opportunity)

0222 Radiative Processes in Air Excited by an ArF laser—Studies are directed toward the use of fluorescence to measure temperature.

0223 Venturi Air-jet Vacuum Ejector for Sampling Air—Fast response in measurement of CO is achieved.

Other Items of Interest

0109 Estimating Fumigant Residues

0173 Mercury Analysis to Meet Water Quality Criteria

0174 Supercritical Oxidation Destroys Aqueous Toxic Wastes

0205 Separation of Chromosomal Length DNA Molecules: Pneumatic Apparatus for Rotating Gels During Electrophoresis

Fermi National Accelerator Laboratory

Compact Double-detector Radiation Monitor

A compact double-detector radiation monitor to permit dose rate and contamination surveys (Minimeter) has been developed at Fermilab. This instrument substitutes for two individual survey meters: a dose rate instrument and a contamination instrument with a pancake detector. The user's hands are freed during transport because the instrument is carried in a leather belt-pouch. This is an improvement over existing technology because other multi-function instruments require at least one external detector assembly (probe/cable) which can prove clumsy during belt transport. The Minimeter utilizes two internally mounted detectors: an energy compensated GM detector for dose rate and a 2-inch diameter thin window pancake GM detector for contamination surveys.

For Additional Information:

Office of Research and Technology Applications
Fermi National Accelerator Laboratory
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Refer to FAA-1557/TN

Department of Energy

Technology Application

Fermi National Accelerator Laboratory

Dead-time Compensation Circuit for Radiation Survey Meter

Radiation survey instruments are an important component of the Fermilab accelerator safety program. Frequently, instrumentation that meets the safety needs and user requirements of the Laboratory is not available commercially. For this reason, Fermilab's Safety Section has been involved in the design or modification of survey instruments for almost two decades. The following is a brief summary of some of the instrumentation developments and design modifications that have recently taken place at Fermilab:

There is a licensing opportunity available for a dead-time compensation circuit developed in conjunction with a log display radiation survey meter designed at Fermilab. The circuit compensates for dead time over a wide range of count rates by producing a dead-time pulse for each detected event, a live-time pulse spanning the interval between dead-time pulses and circuits that average the value of these pulses over time. The logarithm of each of these averaged values is obtained and the logarithms are subtracted to provide a signal that is proportional to the logarithm of the count rate that is corrected for the effects of dead time. The circuit produces a meter indication and is also capable of producing an audible indication of detected events.

The Fermilab designed Log Survey Meter (LSM) is an improvement over existing technology because it provides a means for correcting for the dead time inherent in a Geiger counter or any other detector subject to dead-time counting losses.

The LSM has a transverse mounted, energy compensated Geiger tube in a magnetically shielded, T-shaped probe which contains the high voltage bias and discriminator circuits. It operates from 2 - 2,000 mr/hr with no range switches. This light weight, extremely serviceable instrument was ergonomically designed and contains a luminous meter scale.

This new dead-time compensation technology could be used with any pulse counting application requiring a logarithmic display with wide dynamic range and compensation for detector/electronic dead time.

For Additional Information:

Office of Research and Technology Applications
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Refer to FAA-380/TN

Lawrence Berkeley Laboratory

Particle Sizer Bridges Gap Between Visible Light and X-Rays

A technique that uses the scattering of low energy x-rays to measure the size and shape of objects too small to be seen with visible light but too large for conventional x-ray imaging techniques, has been developed by scientists at LBL.

This new technique was developed by James Underwood, Rupert Perera, and Dana Berkeland, at LBL's Center for X-Ray Optics. It can be used to measure particles between .01 and 1.0 microns (millionths of a meter) in size - a range into which fall many biological particles, including proteins.

When a beam of electromagnetic radiation strikes an object, its light waves are scattered. These scattered waves form interference patterns with unscattered waves of the same light that can be mathematically interpreted. The effectiveness of this method of measurement, which is called "small angle scattering," depends on the size of the object and the wavelength of the scattered light.

If the object is much larger than the wavelength, then experimenters can not resolve the scattered waves from the incident beam. If the object is much smaller, the scattered waves will be widely spread and the resulting pattern will be too weak to observe, according to the researchers.

At wavelengths between 10 to 50 angstroms, low energy or "soft" x-rays are the perfect size for measuring micron and submicron objects. Until now, however, soft x-rays could not be used for small angle scattering because of the limitations of existing optical systems which depend on pinholes or tiny slits to focus radiation. The LBL scientists overcame these limitations by collecting and focusing soft x-rays with a multilayered mirror.

A multilayered mirror consists of alternating coats of tungsten and carbon, stacked one on top of the other (using an ion-sputtering technique) over a curved surface. The multilayered coatings make the mirror highly reflective of soft x-rays and the curved surface enables the reflected radiation and any interference patterns it carries to be focused to a point.

The soft x-ray small-angle scattering system is a relatively simple affair, consisting basically of a sample chamber, a multilayer mirror, and a detector. Particle samples are placed in front of the mirror, a beam of soft x-rays is sent through them, and the diffracted radiation is reflected back into the detector.

With their technique, the LBL researchers say they should be able to look at biological materials without removing them from their natural aqueous environments, or causing extensive radiation damage. An example would be the observation of striations of muscles or tendons.

This new small angle scattering system is now being used with a laboratory-scale source of soft x-rays. However, it is especially well-suited for use with the Advanced Light Source, an electron synchrontron under construction at LBL which will provide the brightest coherent beams of soft x-rays ever produced.

FOR ADDITIONAL INFORMATION: Public Information Department, ATTN: Lynn Yarris, Lawrence Berkeley Laboratory, Berkeley, CA 94720; Telephone (415)486-5375.

NIST Technology Update

National Institute of Standards & Technology

U.S. Department of Commerce, Gaithersburg, MD 20899

Inexpensive Frequency Calibration Service Available

The NIST Automated Computer Time Service (ACTS), a dial-up service begun in 1988, can also act as an inexpensive frequency calibration service. NIST researchers have found that a frequency calibration accuracy of better than one part in a billion is readily available from a single long telephone call or from a sequence of short calls averaged over a few days. The cost of hardware and software for ACTS is only about $100 versus up to several thousand dollars for most other frequency dissemination services with this level of accuracy.

FOR ADDITIONAL INFORMATION: Access ACTS by dialing 303/497-4774. Software can be obtained for $36 from the Standard Reference Materials Program, Rm. 204 Bldg. 202, NIST, Gaithersburg, Md. 20899: 301/975-6776. Ask for Automated Computer Time Service, RM 8101. The system will work with modems with rates of 300 bits/second or 1200 bits/second. Modems at 300 bits/second seem to offer better stability. Paper no. 44-90 describes the service and is available from Jo Emery, Div. 104, NIST, Boulder, Colo. 80303; 303/497-3237.

NASA Tech Brief
National Aeronautics and
Space Administration

Electrostatic Dispersion of Drops in Clusters

Electrical charging can speed evaporation.

A report presents a theoretical study of the evaporation and dispersion of electrostatically charged clusters of drops in liquid fuel sprays. The report represents an extension of the studies described in the preceding article, "More About Evaporation of Drops in Clusters" (NPO-17594). This study was undertaken in an effort to learn how electrostatic atomization can be used to disperse fuel better in order to reduce the formation of soot in diesel engines and other power and combustion systems.

Except for the addition of electrostatic effects, the mathematical model of the cluster of drops is the same as in the study described in the preceding article. Calculations based upon this model are made for charged as well as uncharged clusters of drops. The charge is varied from zero to the maximum possible charge found empirically in hydrocarbon sprays. The two models of turbulence mentioned in the preceding article are also used.

The models are used to perform a numerical simulation for n-decane drops evaporating in air under conditions representative of those in a combustor. Although the model of the cluster does not pertain directly to conditions in diesel chambers, in that it includes the assumption of atmospheric pressure, it nevertheless provides valuable insights into some of the fundamental differences between the behaviors of charged and uncharged drops.

The results of the simulation show that in the dense-cluster regime, the evaporation of the drops can be speeded considerably by electrostatic charging and that turbulence affects the rate of evaporation much less than does electrostatic charge. The results for the dilute-cluster regime show that turbulence does not have much of an effect on evaporation, whether or not electrostatic charge is present, but that the loss of fuel vapor from the cluster can be speeded by an increase in turbulence and decreases in the size of the cluster and/or in electric charge.

Calculations pertaining to soot are not performed. Instead, the authors draw inferences regarding the impact of electrostatic charge on the control of soot in heterogeneous flames, based on the prior experimental data on soot formation in well-defined sprays.

This work was done by Josette Bellan and Kenneth G. Harstad of Caltech for **NASA's Jet Propulsion Laboratory**. *"Electrostatic Dispersion of Drops in Clusters."* *NPO-17516/TN*

FOR ADDITIONAL INFORMATION: *Contact: Director, Technology Transfer Division, P.O. Box 8757, BWI Airport, MD 21240; (301) 621-0100 Ext. 241*
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NASA Tech Brief
National Aeronautics and Space Administration
NASA's Jet Propulsion Laboratory, Pasadena, California

Linear Ion Trap for Atomic Clock

Second-order Doppler shift of the ion absorption frequency is reduced.

A linear, radio-frequency ion trap increases the frequency stability of an atomic frequency standard device over that of a similar device equipped with a conventional point ion trap. Measurements on a prototype show that the stability should be increased by a factor of 4 to 5. With proper design and adjustment, it should be possible to increase the frequency stability to 10 times that of a device with a point trap.

The figure illustrates schematically the point and linear ion traps. All ion traps confine ions around the nodes or zero points of a radio-frequency electric field. Electrostatic repulsion between ions tends to keep them away from each other and away from the node of the trap. Away from the node, an ion is driven into motion by the radio frequency field and, consequently, the Doppler shift in its absorption frequency grows with its distance from the node. In a conventional single-node trap, the spread of ions around the node and the consequent motion results in a second-order Doppler shift about 10 times the minimum possible shift (which is the shift due to thermal motion at room temperature).

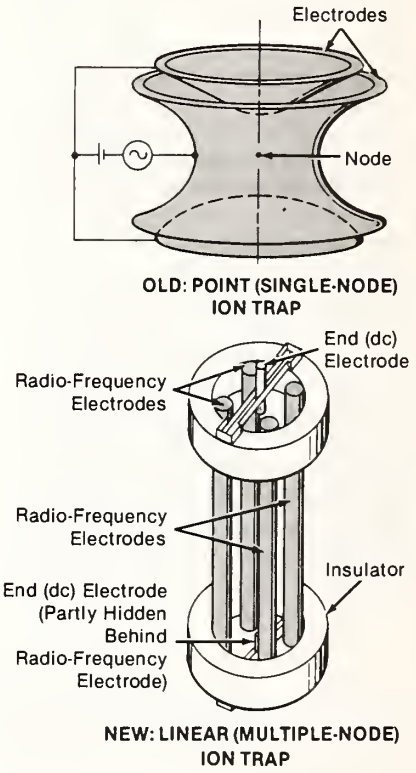
In contrast with the older point ion trap, which produces a single node, the linear ion trap produces a line of nodes of the radio-frequency field along its axis. The resulting force on ions in this field is directed toward this axis, confining the ions in the radial direction. A positive constant voltage is applied to axial end electrodes to obtain axial confinement.

In the linear ion trap, the ions are on average much closer to the nodes than they are in the point trap. That is, for the same number of ions placed in the point and linear traps, the linear trap holds ions closer to the zero-field node line. Thus, the radio-frequency motion and the resultant Doppler shift are smaller in the linear trap. The improvement can be expressed quantitatively by

$$\frac{\text{frequency offset in linear trap}}{\text{frequency offset in point trap}} = \frac{\text{radius (R) of ion cloud in point trap}}{\text{length (L) of ion cloud in linear trap}}$$

Alternately, a linear trap can store (L/R) times the ion number as a conventional point trap with no increase in average second-order Doppler shift. This ratio is about 20 for the prototype linear trap. This increases the signal-to-noise ratio in the measured atomic resonance used to generate the stable output frequency.

This work was done by John D. Prestage of Caltech for **NASA's Jet Propulsion Laboratory.** *NPO-17758/TN*



The **Linear Ion Trap** confines ions with less radio-frequency motion than does the point ion trap.

FOR ADDITIONAL INFORMATION: *Contact: Director, Technology Transfer Division, P.O. Box 8757, BWI Airport, MD 21240; (301) 621-0100 Ext. 241*
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NASA Tech Brief
National Aeronautics and Space Administration

More About Evaporation in Clusters of Drops

Several mathematical models are used to study transport of species, mass, and heat.

A report presents a theoretical study of evaporation in clusters of spray drops in liquid fuel. The report is related to the reports described in "Turbulence and Evaporation in Clusters of Drops" (NPO-17323) and "Effects of Turbulence on Ignition" (NPO-17335), *NASA Tech Briefs* Vol. 13, No. 10, pages 45 and 46. The purpose of this study is to improve the theoretical description of the transport of molecular species, mass, and heat between a cluster and its surroundings.

The study involves two similar mathematical models of the cluster and its interactions. In both cases, there is assumed to be a spherical cluster of spherical drops (all of the same size) of a single-component liquid. The cluster is assumed to move axially as an entity through an ambient gas, which is at a temperature higher than that of the drops and at constant pressure. The drops move radially in the cluster in a self-similar manner that preserves the uniform distribution. Each drop of the cluster is considered to be surrounded by a fictitious sphere of influence, the radius of which is half the distance between the centers of two adjacent drops.

Both models take account of the transfers of momentum, species, mass, and heat between the liquid and gaseous phases within the cluster and between the cluster and the ambient gas. The exchange of momentum is due to evaporation and two drag forces: one for the individual drops and one for the cluster as an entity. To calculate the transport of mass, species, and heat from the cluster to the surroundings, the first model of the cluster ignores the radial velocity and uses an ad-hoc "trapping factor," which is a weighting factor that represents situations intermediate between those of dilute clusters, wherein mass is assumed trapped, and dense clusters, from which mass is assumed to escape to ambient. In the second model of the cluster, the transport can be calculated explicitly, without assuming a trapping factor, because in this model, both the drops and the gas are considered to have self-similar radial velocities.

Two models of turbulence are used to calculate the transport of mass, species, and heat from the surroundings. In turbulence model 1, turbulence is assumed to build up with time as the axial velocity of the gas inside the cluster increases and the relative axial velocity between the drop and gas decreases correspondingly. In turbulence model 2, turbulence is assumed to be present initially.

The numerical results of both models show that transport processes are unimportant for dilute clusters but become crucial for dense clusters of drops. The results also show that transport processes are more important for smaller clusters of drops in the dense regime. Although the qualitative behavior of the two cluster models is similar, substantial quantitative discrepancies appear in the dense-cluster regime. The authors suggest that comparisons of global models like these with experimental data on evaporation times in the dense-cluster regime would be helpful in the evaluation and improvement of the models.

The numerical results also show that the fuel-loss ratio depends strongly on the size of the cluster and the model of turbulence, whereas the total loss of mass is nearly insensitive to turbulence except in the case of small clusters. Overall, the numerical trends show that global cluster models like these look promising because, despite their simplicity, they account at least semiquantitatively for the major physical phenomena in the evaporation of sprayed liquid fuels.

This work was done by Josette Bellan and Kenneth G. Harstad of Caltech for **NASA's Jet Propulsion Laboratory.** *"Transport-Related Aspects of Dense Spray Evaporation."*
NPO-17594 /TN

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NASA Tech Brief
National Aeronautics and Space Administration
Goddard Space Flight Center, Greenbelt, Maryland

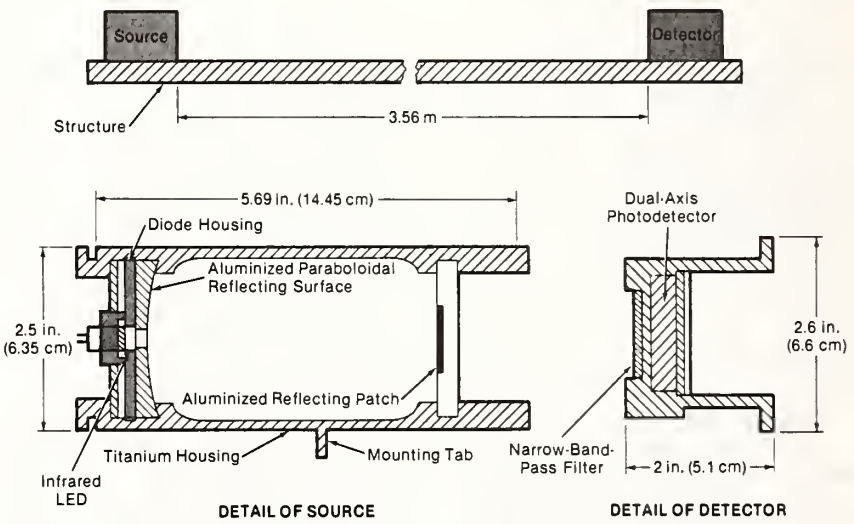
Monitoring Small Deformations in an Instrument

Relatively simple source/detector pairs measure changes that affect optical alignment.

A system for monitoring small thermal, gravitational, and dynamical deformations in an x-ray telescope includes two sources of infrared light, each associated with a dual-axis, position-sensing photodiode. The principle of operation is straightforward and applicable to the monitoring of small lateral translations and/or rotations between different parts in machinery, buildings, bridges, ships, and other large structures.

The infrared sources and detectors are mounted on two parts of the structure, between which relative deformations are to be measured. In the x-ray telescope, each infrared source is mounted on the baseplate that holds the glancing-incidence x-ray mirrors, while its associated detector is mounted on a shelf that holds the x-ray detector. The distance along the axis of the telescope from the infrared sources and the glancing-incidence x-ray mirrors to the infrared and x-ray detectors is about 3.56 m.

Each infrared source (see figure) includes a light-emitting diode (LED) with a nominal emission wavelength of 820 nm, which nearly matches the wavelength of peak sensitivity of its associated detector. Radiation from the LED enters along the optical axis of the source through a hole in a paraboloidal reflector. After reflection from a flat central aluminized patch on an otherwise infrared-transparent window, the radiation is gathered by the paraboloidal reflector, transmitted through the transparent annulus of the window, and focused on the detector at the far end of the optical path. The housing of the source is made of titanium, which was chosen because its coefficient of thermal expansion matches that of the paraboloidal reflector. This reduces thermal stresses, thereby helping to preserve alignment over the required temperature range of 0 to 40 °C.



The **Source and Detector**, each mounted on a different part of the structure, measure rotations between, or lateral deflections of, those parts.

The dual-axis position-sensing photodiode in each infrared detector is mounted in an aluminum housing. To reduce the component of detector noise due to ambient light, the photodiode, which has a spectral response from 350 to 1,040 nm, is shielded by a narrow-band-pass filter that transmits at 820 nm with a half bandwidth of 80 nm and blocks the rest. The output of the detector consists of a difference voltage and a sum voltage for each axis. The ratio of the difference voltage to the sum voltage for each axis indicates the position of the centroid of the radiation falling on the detector. This position gives a measure of the relative rotation and/or lateral translation between the source and detector.

The source/detector pairs were calibrated for the expected range of temperatures. The addition of various errors resulted in a total three-standard-deviation error of 102 μm rms on either axis in the detector plane. At the 3.56-m baseline length, this represents an angular error of less than 6 arc seconds rms, which is within the maximum specified error of 15 arc seconds.

This work was done by John G. Hagopian of **Goddard Space Flight Center** *and William Northcutt of Fairchild Space Company.* *GSC-13271/TN*

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NASA Tech Brief
National Aeronautics and Space Administration
Lewis Research Center, Cleveland, Ohio

Licensing Opportunity

Processing Laser-Velocimetric Data by Vector Scanning

Velocity plots can now be obtained in minutes instead of hours.

Vector scanning (see Figure 1) is a technique for processing flow-field data from pulsed-laser-velocimetry images into two-dimensional velocity-vector maps. Vector scanning requires no special equipment other than a charge-coupled-device (CCD) camera, circuitry to digitize the output of the camera, and a computer. Once the image data are digitized, all processing is done in the computer.

The conventional technique for reducing laser-velocimetric data requires photographic plates to be multiply exposed, developed, and scanned with special equipment to extract the raw image data, which are then processed into velocity-vector maps. This technique requires several hours to make each velocity map, whereas the vector-scanning technique requires only minutes and can sometimes be performed during a measurement.

To perform a vector-scanning measurement, a flow field is seeded with micronized particles of aluminum oxide, and the plane in which velocities are to be measured is illuminated with a sheet of light from a continuous-wave laser. The CCD camera records a sequence of five successive images of the illuminated particles in the flow field. The minimum time between images is one-sixtieth of a second. The raw, digitized-image data from the camera are preprocessed to determine the centroid of the image of each particle in each flow-field image. The particle-position centroids from each flow-field image are then represented by points of equal brightness at the picture elements (pixels) nearest the centroids, thus forming a map of the particle positions. The brightness of the centroid images of each successive flow-field image is made twice the brightness of those of the preceding flow-field image. The five brightness-coded, flow-field image maps are then combined into a single map that shows the time/space history of each particle in the flow field.

The vector-scanning algorithm then processes the five-exposure-map data by a searching operation that is reminiscent of convolution except that it is faster because it involves only logic operations and no arithmetic. First, the operator enters the expected range of flow speeds and angles to be searched. For each flow speed and angle, a particle that moves at the corresponding velocity is identified in the image as a line sequence of five intensity-coded picture elements. The computer assigns that velocity to each such sequence. The points that have not been assigned to particle/velocity sequences are scanned again for conformity or nonconformity to patterns representing other velocities. This process is repeated automatically until all of the coded-intensity centroid images are either assigned to particle/velocity sequences, found to be parts of incomplete sequences, or otherwise accounted for.

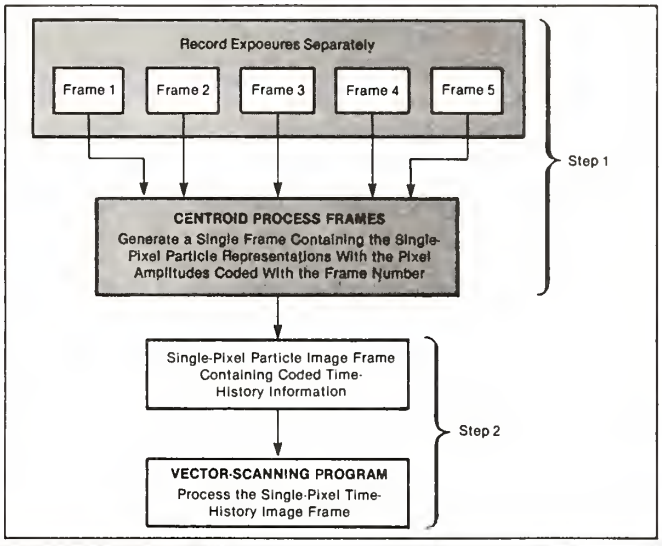
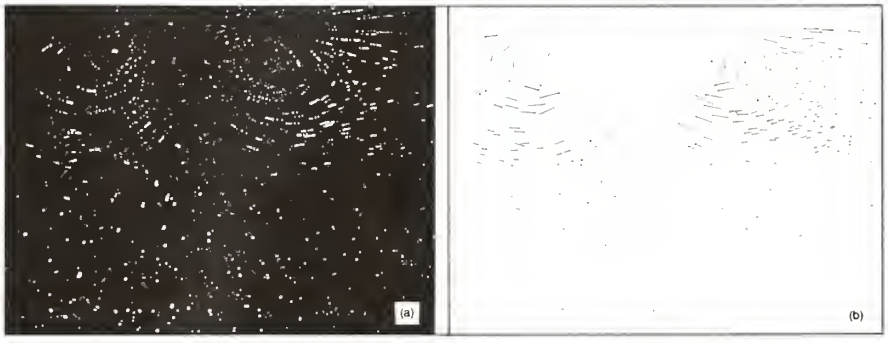

Record Expoeures Separately
Frame 1
Frame 2
Frame 3
Frame 4
Frame 5
Step 1
CENTROID PROCESS FRAMES
Generate a Single Frame Containing the Single-Pixel Particle Representations With the Pixel Amplitudes Coded With the Frame Number
Single-Pixel Particle Image Frame Containing Coded Time-History Information
Step 2
VECTOR-SCANNING PROGRAM
Process the Single-Pixel Time-History Image Frame

Figure 1. **Vector-Scanning Two-Step Processing Algorithm**, processing step 1 produces the time-history coded image frame ready for analysis by the vector-scanning program in step 2. The output of step 2 is the two-dimensional velocity-vector map.



CCD IMAGE VELOCITY-VECTOR MAP

Figure 2. **Particles In a Circulation Fluid** are illuminated by a pulse of laser light (a). A sequence of images like this one is processed to obtain the velocity-vector map shown in (b).

Figure 2 (a) shows the image of the pulse-illuminated particles suspended in a heated-fluid experiment recorded by a 512×488 picture elements CCD. Five successive frames like this one were recorded at intervals of 660 ms. All computations were performed in FORTRAN 77 on a 25-MHz personal computer containing an 80386 microprocessor. It took only 350 seconds to process the raw image data into the velocity-vector map shown in Figure 2(b). More recent work indicates data processing time can be reduced by two orders of magnitude. No array processors or specialized hardware are required for implementing the vector-scanning technique.

This work was done by Mark P. Wernet of **Lewis Research Center.**

This invention is owned by NASA, and a patent application has been filed. Inquiries concerning nonexclusive or

exclusive license for its commercial development should be addressed to the Patent Counsel, Lewis Research Center. Refer to LEW-14925/TN.

Lewis Research Center

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NASA Tech Brief
National Aeronautics and
Space Administration

Radiative Processes in Air Excited by an ArF Laser

Studies are directed toward the use of fluorescence to measure temperature.

A report describes experimental and theoretical studies of the emission spectrum of air excited by light from an ArF laser. The purpose of the studies was to determine the conditions under which fluorescence from O_2 could be used to measure temperatures in aerodynamic flows.

In the proposed laser-induced fluorescence technique, laser radiation at a wavelength of 193 nm would be used to excite selectively one or more rotational transitions in the Schumann-Runge

$$(B^3\Sigma_u^- - X^3\Sigma_g^-)$$

band of O_2. The intensity of the resulting fluorescence should be proportional to the population density of the ground state, which in turn is sensitive to the temperature of the air.

In the experiments, the emission from the focal region of the laser beam was collected in a direction perpendicular to the axis of the beam, focused on the entrance slit of a grating monochromator, and detected by a photomultiplier. The spectral analysis was confined to emission at wavelengths below 260 nm to avoid fluorescence in most window materials. By a theoretical calculation that incorporated the spectral distribution of the incident laser beam, the observed fluorescence spectrum was corrected for the absorption of the laser radiation by air along the beam (that is, not in the focal region).

In addition to the expected fluorescence from O_2, the emission spectrum was found to include significant contributions from the near-resonant Raman fundamental and overtone bands. In a conceptual temperature-measuring system that was uniformly efficient over the spectral range of interest, the Raman radiation would dominate the spectrum, thereby reducing the sensitivity of the system to the temperature. Therefore, in a practical system, one might prefer to filter the spectrum to remove the Raman contributions.

The fluorescence spectrum was also found to contain four-photon fluorescence excitation of carbon produced from atmospheric CO_2 and three-photon excitation of O_2^+. The interference of these effects with fluorescence measurements of temperature could be reduced very simply by reducing the intensity of the incident laser beam.

This work was done by Robert L. McKenzie and Winifred Huo of **Ames Research Center** *and Gabriel Laufer of ANALATOM, Inc. "Radiative Processes in Air Excited by an ArF Laser."*
ARC-12136/TN

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NASA Tech Brief
National Aeronautics and Space Administration
Langley Research Center, Hampton, Virginia

Venturi Air-Jet Vacuum Ejector for Sampling Air

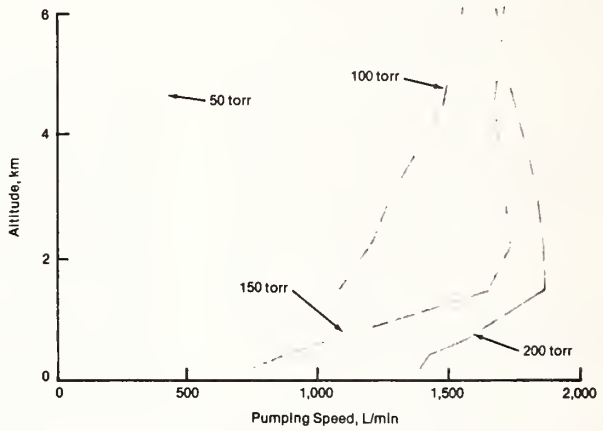
Fast response in measurement of CO is achieved.

The NASA Global Tropospheric Experiment program includes many trace-gas-sensing experiments that require sampling of ambient air by use of aircraft. These experiments require some form of air-flow system, which generally includes mechanical vacuum pumps. The vacuum pump is the principal component of instrumentation needed to achieve the fast response required for measurements of flux. Mechanical vacuum pumps collectively constitute a heavy payload, use many kilowatts of aircraft electrical power, and generate much heat that is often impossible to dissipate satisfactorily.

An alternative type of vacuum pump that has many desirable characteristics for use in aircraft is the venturi air-jet vacuum ejector. This pump is light in weight, requires no electrical power, does not contribute heat to the aircraft, and can provide high pumping speeds at moderate suctions. The high-pressure motive gas required for this type of pump can be bled from the compressor of an aircraft engine with negligible effect on the performance of the engine.

A venturi pump is now being used as a source of vacuum for the differential-absorption CO-measurement (DACOM) instrument developed at the NASA Langley Research Center. The DACOM is being modified to achieve in situ measurements of CO at a frequency response of 10 Hz. This frequency response will provide an improvement in spatial resolution and can potentially lead to a capability to measure the turbulent flux of CO by use of the eddy-correlation technique.

To achieve such fast response in this instrument, the high rate of flow of 17-standard cubic feet per minute (8×10^{-3} standard cubic meters per second) must be achieved at a suction of 200 torr (27 kPa). The mechanical pump capable of delivering this performance weighs approximately 500 lb (227 kg) and consumes approximately 6 kW of electrical power, which is dissipated in the cabin of the aircraft. In contrast, the venturi pump specifically designed for DACOM weighs approximately 20 lb (9.1 kg), consumes no electrical power, and does not heat the cabin.



The **Performance of the Venturi Pump** meets or exceeds design specifications.

This venturi pump was recently installed on the Electra aircraft that is based at the NASA Wallops Flight Facility and that has successfully completed a series of test flights. The pump was rigidly mounted on the fire wall within the compartment of engine 3 and connected to the DACOM instrument via a 15-ft. (4.6-m) vacuum line. The pump was designed to use motive gas [475 °F (246 °C), 80 psi (0.55 MPa), 64 standard cubic feet per minute (3.0×10^{-2} standard cubic meters per second)] from the 14th stage of the compressor 3 to achieve the required flow and suction.

During the flight tests, the pressure and temperature of the motive gas as well as the pressure and rate of the suction flow were monitored. The pumping speed of the venturi pump was determined as a function of altitude from sea level to 20,000 ft (6.1 km), pressure of the motive gas from 55 to 95 psi (0.38 to 0.66 MPa), speed of the aircraft from 180 to 250 kn (93 to 129 m/s), and suction from 50 to 300 torr (7 to 40 kPa) (see figure). The performance of the venturi pump met or exceeded the design specifications. Venturi pumps with higher pumping capacities are also available and can be installed without significant impact upon the supply of motive gas.

This work was done by Gerald F. Hill, Glen W. Sachse, and L. Garland Burney of **Langley Research Center** *and Larry O. Wade of Planning Research Corporation.* *LAR-14024/TN*

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Transportation & Components

0224 Surface Effect Ship (SES) Technology

0225 Shaft Adapter for Data Coupler—A sleeve and clamp provide for accurate measurements of stresses and strains in a shaft. (Licensing Opportunity)

0226 Tests of a Differential Global Positioning System—Performance of a helicopter-approach navigation system is described.

Software

0227 Code for Analysis of Wing-and Flap Systems—Effects of leading- and trailing-edge flaps are included.

0228 Wing-Design and -Analysis Code—The new version features improved numerical accuracy and additional capabilities.

U.S. Navy Fact Sheet

David Taylor Research Center

Surface Effect Ship (SES) Technology

The Surface Effect Ship (SES) technology began in 1960, funded by the Foundation Research Program at the Naval Air Development Center, Warminster, PA. At that time Ground Effect Machines (GEMs) had large "daylight gaps" of blown air between their hard structure and the ground, and a large penalty resulted from larger (realistic) craft weights. The Captured Air Bubble Vehicle envisioned a captive region of air retained on the sides by sidewalls, and fore and aft by end seals that moved up and down in response to waves. This allowed realistic craft weights without incurring excessive air system power penalties. By the time a U.S. patent was issued on this concept in 1964, the Navy's XR-1 experimental research craft had been designed and built and was in operation. In 1965, the David Taylor Research Center (DTRC) accepted technical leadership of this effort.

By 1967, the Maritime Administration study "Surface Effect Ships for Ocean Commerce" had adopted the foregoing concept, and together with the Navy, was in the process of setting up an SES management team. This team ultimately the Navy's SES Project Management Office (PMS-304), built the SES-100A, a waterjet propelled 100-ton SES testcraft, and the SES-100B, propelled by semisubmerged supercavitating propellers. This latter 100-ton SES achieved a 92-knot speed and a world record. A 3000-ton "3KSES," a 70-to 80-knot ASW frigate, was also designed.

A parallel SES development in the early 1970s, funded by the Independent Exploratory Development (IED) Program at DTRC, was the high length-to-beam ratio SES concept. This concept promises significantly reduced power for SESs, of reasonably high speed (e.g. 50 to 55 knots at frigate size), less reduction in speed in higher sea states, and improved seakeeping characteristics. This IED program led to a better understanding of this class of SESs through predictions of high L/B SES drag and powering characteristics for calm water and in waves and verification of these characteristics through SES model tests in DTRC towing tanks. These tests addressed not only drag and powering, but also stability, structural loads, and designs that resulted in good seakeeping characteristics. The XR-5—the experimental SES research manned testcraft—and the USN DTRC SES-200 were designed, built, and evaluated as part of this program.

In the United States, Textron Marine, Inc., of New Orleans has built a number of SESs for commercial use, for the U.S. Coast Guard for its drug interdiction duty in Key West, Florida, and for the U.S. Navy. The major construction of commercial SESs (about 130 craft) has been in England, principally for export. Norway has recently built a number of SESs for Norwegian coastline SES ferry operations and has also exported some craft. A group of mine warfare ships, based on this ferry experience, is now in the design and construction phase in Norway. Sweden has also built several SES ferries. Germany is now doing design verification of a 700-ton fast SES testcraft (Eprobungsboot Schnell). The French Navy is building the NES-200, a 200-ton SES testcraft, with an ASW frigate planned in the future. The Spanish have a 30- to 50-ton SES testcraft in fabrication and intend to build an SES fast patrol boat in the future. There is an Italian plan similar to that of Spain.

FOR ADDITIONAL INFORMATION: Dr. Basil Nakonechy (Code 0117), David Taylor Research Center, Bethesda, MD 20084-5000; (202)227-1307.

NASA Tech Brief
National Aeronautics and Space Administration
Langley Research Center, Hampton, Virginia

Licensing Opportunity

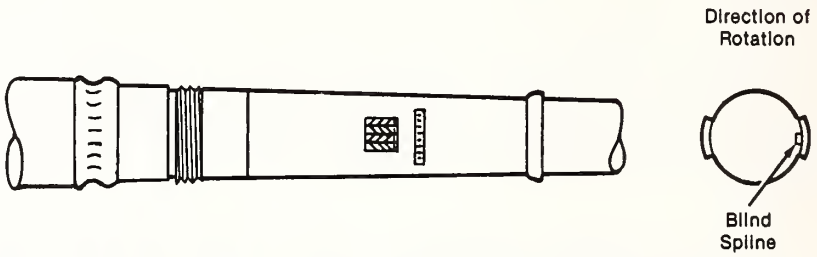
Shaft Adapter for Data Coupler

A sleeve and clamp provide for accurate measurements of stresses and strains in a shaft.

A shaft adapter was developed to provide a means for securing the Acurex 1200B universal data coupler to a rotating instrumented shaft: in this case, that of the tail rotor of a helicopter, The shaft adapter was needed because there were no internal or external means for securing the fiberglass transmitting collar of the data coupler and the available space was limited by the addition of strain gauges on the tapered shaft. The only other device capable of transmitting data from rotating to stationary points is a slipring. However, sliprings have the disadvantages of wear and the unreliability of electrical brush contacts.

The shaft adapter consists of two major parts: the shaft sleeve and the shaft clamp. The shaft sleeve consists of two identical halves, each of which has a window for the strain gauges (see figure). The shaft clamp also consists of two halves. The shaft clamp is keyed to the shaft sleeve to keep the sleeve from moving. The transmitting collar of the data coupler is likewise keyed to the sleeve.

Spacers and spacer washers keep the installation torque, or compression, of the collar and the sleeve from being imparted to the shaft. Rubber is also bonded to the inside of the sleeve to absorb vibration. The structural system is designed to minimize any change in the load paths where loads are transmitted from the rotor blades via the shaft to the differential gearbox housing, since a minimum change in the load path resuits in inaccurate readings from the strain gauges.



The **Shaft Sleeve Has Windows** for strain gauges mounted on the tapered rotor shaft.

This system provides undistorted and accurate readings of stresses and strains in the shaft. Unlike a slipring device, it has no electrical contacts to wear out and cause problems. This system should be able to operate in a high-vibration flight environment for long times and in other situations in which it is necessary to transmit data on the stresses and strains in shafts during long times.

This work was done by James R. Elliott and Mark T. Lord of **Langley Research Center.**

This invention is owned by NASA, and a patent application has been filed. Inquiries concerning nonexclusive or exclusive license for its commercial development should be addressed to the Patent Counsel, Langley Research Center. Refer to LAR-13805/TN.

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FOR ADDITIONAL INFORMATION: *Contact: Director, Technology Transfer Division, P.O. Box 8757, BWI Airport, MD 21240; (301) 621-0100 Ext. 241*
REFER TO THE NUMBER LISTED AT THE END OF THIS ARTICLE

NASA Tech Brief
National Aeronautics and
Space Administration

Tests of a Differential Global Positioning System

Performance of a helicopter-approach navigation system is described.

A paper describes validation tests of a global positioning system (GPS) for low-flying helicopters. The system is configured as a differential GPS, in which components in both the aircraft and the ground station compute the position errors relative to a known location using satellite navigational data. Differential GPS corrections are computed from the differences between computed and measured ranges to four satellites being tracked by the receiver in both the aircraft and ground systems. The tests were conducted to determine whether the equipment and computer programs of the system operated correctly and consistently.

The tests were carried out with a helicopter on the ground next to the ground-based equipment. The range-bias errors identified by the equipment on the ground and the equipment in the aircraft were sufficiently well correlated to justify the conclusion that the components were operating properly and that flight testing could proceed. The average error in static tests was less than 1.7 meters in all three coordinate axes — less than predicted by theory. In dynamic tests where the helicopter performed terminal approach operations, the lateral error was less than 6 meters and the vertical error was less than 8 meters.

The tests showed that range-domain filtering is an effective means of reducing noise in the differential corrections transmitted by the ground station. However, integrating monitoring features should be built into the ground system to indicate the performance level in real time and to detect substandard operation.

This work was done by F.G. Edwards, and D.M. Hegary of **Ames Research Center** *and R.N. Turner, F. van Graas, and S. Sharma of Ohio University. "Validating the Airborne and Ground Based Components of a Differential GPS System." ARC-12313/TN*

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Code for Analysis of Wing-and-Flap Systems

Effects of leading- and trailing-edge flaps are included.

The SUBAERF2 program was developed to provide for the analysis of the subsonic aerodynamics and the design by iteration of low-speed wing/flap systems. SUBAERF2 is based on a linearized-theory lifting-surface solution but also accounts for some nonlinear characteristics. It is particularly well suited to configurations that, because of the requirements of high-speed flight, must employ thin wings with highly swept leading edges. The program is applicable to wings with either sharp or rounded leading edges. This program is a new and improved version of the programs described in LAR-13116 and LAR-12987, and replaces both of them.

The low-speed-aerodynamic-analysis method used in SUBAERF2 provides estimates of wing performance that include the effects of attainable leading-edge thrust and vortex lift associated with leading-edge flow separation. The basic aerodynamic-analysis method has been improved to provide for the convenient, efficient, and accurate treatment of simple leading-edge and trailing-edge flap systems. The user puts in the flap geometry directly. Solutions can be found for various combinations of deflections of leading- and trailing-edge flaps. The program provides for the simultaneous analysis of up to 25 pairs of schedules of deflections of leading-edge and trailing-edge flaps.

The SUBAERF2 program is written in FORTRAN V for batch execution and has been implemented on a CDC 175 computer operating under NOS 2.4 with a central-memory requirement of approximately 115K (octal) of 60-bit words. This program was originally developed in 1983 and later revised in 1988.

This program was written by Christine M. Darden of **Langley Research Center** *and Harry W. Carlson of Planning Research Corp.*
LAR-13994/TN

FOR ADDITIONAL INFORMATION

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Wing-Design and -Analysis Code

The new version features improved numerical accuracy and additional capabilities.

The WINGDES2 computer program provides a wing-design algorithm based on a modified linear theory that takes into account the effects of attainable leading-edge thrust. A primary objective of the WINGDES2 approach is the generation of a camber surface as mild as possible to produce drag levels comparable to those attainable with full theoretical leading-edge thrust.

WINGDES2 provides an analysis as well as a design capability and is applicable to both subsonic and supersonic flow. The optimization can be carried out for such designated portions of a wing as leading-and trailing-edge areas, for the design of mission-adaptive surfaces, or for an entire planform such as that of the wing of a supersonic transport airplane.

This program replaces an earlier wing-design code designated WINGDES (see LAR-13315). The new version incorporates modifications to improve numerical accuracy. It also provides additional capabilities, including a means of accounting for the presence of interference pressure fields from airplane components other than the wing, and a direct process for selection of flap surfaces to approach the shape performance levels of the optimized wing surfaces.

WINGDES2 determines an optimum combination of a series of candidate surfaces rather than the more-commonly-used candidate loadings. The objective of the design is the recovery of unrealized theoretical leading-edge thrust of the input surface by shaping of the design surface to create a distributed thrust and thus minimize drag. The input consists of airfoil-section-thickness data, leading- and trailing-edge geometry, spanwise and chordwise station information, and such operational parameters as mach and Reynolds numbers, the angle of attack, and the number of camber surfaces. The output includes optimized camber-surface ordinates, pressure-coefficient distributions, and theoretical aerodynamical characteristics.

WINGDES2 is written in FORTRAN V for batch execution and has been implemented on a CDC CYBER 175 computer operating under NOS 2.4.3 with a central-memory requirement of approximately 167K (octal) of 60-bit words. This program was developed in 1984 and was last updated in 1988.

This program was written by Christine M. Darden of **Langley Research Center** *and Harry W. Carlson of Planning Research Corp.*
LAR-13995/TN

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